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Cynthia T. Brown
Chief, Section of Administration
Office of Procedures
Surface Transportation Board
395 E Street, S.W.
Washington, D.C. 20423-0001

**Re: Finance Docket No. 35517, *CF Industries, Inc. v. Indiana & Ohio Ry., Point Comfort Ry., & Michigan Shore R.R.***

Dear Ms. Brown:

Attached for filing in the above-referenced docket are the Reply Comments of Norfolk Southern Railway Company.

Sincerely,

David L. Meyer /AV

David L. Meyer

Attachment

cc (with attachment): John M. Scheib, Esq.

**BEFORE THE**
**SURFACE TRANSPORTATION BOARD**

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**STB Finance Docket No. 35517**

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**CF INDUSTRIES, INC. v. INDIANA & OHIO RAILWAY COMPANY, POINT COMFORT RAILWAY COMPANY, & MICHIGAN SHORE RAILROAD, INC.**

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**REPLY COMMENTS**
**OF**
**NORFOLK SOUTHERN RAILWAY COMPANY**

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Dated: February 27, 2012

**BEFORE THE**
**SURFACE TRANSPORTATION BOARD**

**STB Finance Docket No. 35517**

**CF INDUSTRIES, INC. v. INDIANA & OHIO RAILWAY COMPANY, POINT COMFORT RAILWAY COMPANY, and MICHIGAN SHORE RAILROAD, INC.**

**REPLY COMMENTS**
**OF**
**NORFOLK SOUTHERN RAILWAY COMPANY**

Norfolk Southern Railway Company ("NS") submits these comments regarding a railroad's ability to address safety and security concerns associated with the transportation by rail of toxic inhalation hazards ("TIH") and poisonous inhalation hazards ("PIH") commodities (collectively, "TIH" commodities).

NS reiterates for the Board that TIH commodities have unique properties that make them inherently dangerous and deadly. When railroads are required to transport these products, they confront extraordinary risks that flow from the nature of the products themselves rather than from any action or inaction by the railroads that must transport them. The companies that manufacture, sell, and profit from these commodities seek to transfer these risks to railroads by placing tank cars containing TIH chemicals in railroad custody as quickly as possible. Unlike those companies, which choose to be in the TIH business, the railroads are not free to decline to participate in TIH transportation because the Board has determined that the federally-imposed common carrier obligation requires them to provide such transportation on demand.

The Board's conclusion that railroads must transport these commodities makes it imperative that the Board apply other aspects of its regulatory framework in a manner that permits railroads to take reasonable steps to address the associated risks and costs. There is no silver bullet. Railroads must have flexibility to:

- take safety precautions themselves aimed at preventing potentially deadly releases of these chemicals;
- give TIH shippers incentives to take the externality costs of their shipping decisions into account before demanding transportation; and
- seek compensation for the extra risk and other costs they bear when they must transport TIH commodities.

No one of these approaches by itself suffices to address the burdens imposed on railroads as a result of the Board's decision to commandeer the Nation's rail network to provide transportation of these deadly chemicals.

This proceeding addresses one facet of the regulatory issues raised by mandatory TIH transportation – what steps a railroad may implement in order to move TIH commodities in a safe and secure manner. The Board should issue a decision confirming that railroads have flexibility to make their own judgments about how to transport TIH commodities in a safe and secure manner on their lines, and specifically that a railroad may implement safety precautions beyond those required by federal law. The particular operational steps that each railroad might choose to adopt undoubtedly will vary according to each carrier's circumstances, and NS accordingly takes no position regarding the reasonableness under the circumstances of the specific provisions contained in the tariffs at issue in this proceeding.

Such flexibility would be consistent with the Board's general approach of leaving to the sound discretion of railroad operating personnel decisions about how to operate their networks safely and efficiently. And, contrary to the views of some commenters, the exercise of such discretion as to TIH commodities would not run afoul of *Consolidated Rail Corp. v. ICC*, 646 F.2d 642 (D.C. Cir. 1981) ("*Conrail*"). The Board has already distinguished that decision on the ground that it arose under a different statutory regime than exists today. *Conrail* is also distinguishable on its facts; the federal regime of safety regulation governing TIH transportation expressly sets only a floor on the actions a railroad must take to handle TIH commodities safely. Accordingly, commenters' reliance on the *Conrail* case is misplaced.

## I. TIH COMMODITIES ARE INHERENTLY DANGEROUS PRODUCTS

There are many toxic inhalation hazards and poisonous inhalation hazards. What they all have in common is that they are inherently dangerous and deadly because of their chemical composition.

For example, although chlorine may have legitimate uses in industry, there can be no dispute that chlorine is inherently dangerous. Indeed, in World War I, chlorine was manufactured specifically to be used as a weapon itself.

- On April 22, 1915, German forces used chlorine gas at Ypres, Belgium against French and Algerian troops.[1]
- On April 24, 1915, German forces used chlorine gas against Canadian forces.[2]

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1 World War I: A Student Encyclopedia, Spencer Tucker, editor, at 474 and 1074 (2006); *see also* Simon Jones, World War I Gas Warfare Tactics and Equipment (2007) (discussing extensively the use of chlorine as weapon in World War I).

2 *Id.* at 474.

- On September 25, 1915, British forces used chlorine gas at Loos.[3]

The horrors of chlorine gas led to an international ban on its use as a weapon of war in 1925 by the Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous or other Gases, and of Bacteriological Methods of Warfare, usually called the Geneva Protocol.[4] Notwithstanding this ban, a report prepared for the United States Air Force documents that Bosnian Muslims used chlorine in shells against Bosnian Serb forces on at least three occasions in 1993.[5]

The harmful effects on the body from chlorine are documented and well known. In 1917, Doctor Arthur Hurst published "Medical Diseases of the War," which discussed the observed effects of chlorine gas on soldiers.[6] Today, the Occupational Safety and Health Administration describes the toxicological effects of chlorine as follows:

> "Severe acute effects of chlorine exposure in humans have been well documented since World War I when chlorine gas was used as a chemical warfare agent. Other severe exposures have resulted from the accidental rupture of chlorine tanks. These exposures have caused death, lung congestion, and pulmonary edema, pneumonia, pleurisy, and bronchitis [Hathaway et al. 1991]. The lowest lethal concentration reported is 430 ppm for 30 minutes [Clayton and Clayton 1982]. Exposure to 15 ppm causes throat irritation, exposures to 50 ppm are dangerous, and exposures to 1000 ppm can be fatal, even if exposure is brief [Sax and Lewis 1989; Clayton and Clayton 1982]."[7]

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3 *Id.* at 232 and 475.

4 The Geneva Protocol prohibits the use of chemical weapons and biological weapons, but does not address production, storage or transfer. These aspects were addressed in later treaties, the 1972 Biological Weapons Convention and the 1993 Chemical Weapons Convention.

5 Theodore Karasik, *Toxic Warfare*, RAND, at 21 (2002) (attached as Exhibit 1).

6 Excerpt available at http://www.vlib.us/medical/gaswar/chlorine.htm (attached as Exhibit 2).

7 Occupational Safety and Health Guideline for Chlorine, U.S. Dep't of Labor, *available at* http://www.osha.gov/SLTC/healthguidelines/chlorine/recognition.html (attached as Exhibit 3). For a further discussion of the toxicology of chlorine, *see* Sylvia S. Talmage, "Chlorine," in Handbook of Toxicology of Chemical Warfare Agents, Ramesh Chandra Gupta, editor (2009).

Similarly, anhydrous ammonia has been used in warfare precisely because of its inherent chemical composition, which makes it deadly when released as a gas. A report for the United States Air Force notes that, during the Bosnia war, Serbian forces targeted a chemical facility in Croatia and caused the release of 70 tons of anhydrous ammonia.[8] Luckily, the nearest town was 30 kilometers away and local authorities had time to evacuate over 30,000 residents.[9] The tactic employed in Croatia is described as "improvised chemical warfare."[10]

In light of the weapon-grade character of these chemicals, experts have not surprisingly estimated that a terrorist attack causing a release of such chemicals in a populated area could cause immense injury and loss of life, potentially leading to liability measured in the tens and even hundreds of billions of dollars.[11]

In this proceeding, a coalition of commenters led by the American Chemistry Council ("ACC") would like to sweep these facts under the rug and focus instead on the cause of any particular derailment.[12] But clearly it is the product itself that poses a risk to railroad employees and the public at large. It is the nature of the product – coupled with the manufacturer's decision to send tank cars loaded with it through the population centers that the Nation's rail network traverses – that makes it attractive to terrorists.[13]

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8 Karasik, *Toxic Warfare* at 22 (Exh. 1).

9 Jonathan B. Tucker, *The Future of Chemical Weapons*, at 14 (Fall 2009/Winter 2010) (attached as Exhibit 4).

10 *Id.*

11 American Academy of Actuaries Comments to President's Working Group on Financial Markets, April 21, 2006, at 30, Appendix II (attached as Exhibit 5).

12 Opening Evidence and Argument of ACC, STB Finance Docket No. 35517, Verified Statement of Frank Reiner at 4 (filed Jan. 13, 2012).

13 Tucker, *The Future of Chemical Weapons*, at 26-28 (Exh. 4).

The transportation itself does not pose the risk. For example, if a train of coal derails, as happens from time-to-time regardless of how much care the railroad exercises, the result is that there may be coal on the ground that must be picked up. Often, no one is hurt. If a train with a car of chlorine derails – whatever the cause – people are at risk because of the attributes unique to these dangerous chemicals.

The manufacturers and users of chlorine and other TIH products are well aware of the toxicological risks associated with their products. Those risks explain why TIH shippers seek every opportunity to transfer tank cars containing these products into the railroads' custody as quickly as possible. For example, one of Dow's concerns with RailAmerica's tariffs in this proceeding is that "[w]here the shipper originates the shipment with a RailAmerica subsidiary, requiring the shipper to tender no more than three cars at a time might result in holding loaded TIH/PIH cars at the shipper's facility."[14] Dow would not want to be responsible for its inherently hazardous and deadly product any longer than it has to be. Apparently, the sooner Dow can hand that chlorine to a railroad and – at least for a time – absolve itself from as much responsibility for it as possible, the better life is for Dow.

## II. UNLIKE COMPANIES THAT CHOOSE TO BE IN THE BUSINESS OF MAKING AND USING TIH COMMODITIES, RAILROADS HAVE NO CHOICE

Railroads have no choice but to transport chlorine and other TIH commodities upon a reasonable request. By contrast, shippers of these chemicals act voluntarily. There are no federal laws or regulations that require a company to choose to be in the

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[14] Opening Evidence of Dow Chemical Co., STB Finance Docket No. 33517, at 24 (filed Jan. 13, 2012).

business of manufacturing, selling, and profiting from chlorine and other TIH commodities. And they make substantial sums of money selling those products.

As one illustration, Olin Corporation has a Chlor Alkoli division. In 2011, Olin, through that division, bought out the 50% share in Sunbelt – a chlorine manufacturer – that its partner, PolyOne, held for $132.3 million in cash plus the assumption of a PolyOne guarantee related to the SunBelt Partnership debt.[15] Olin now owns 100% of the chlorine manufacturer. Why did Olin spend so much money to acquire the portion of Sunbelt it did not already own? According to its Chief Financial Officer, "Olin expects the acquisition to be accretive to both [earnings before interest, taxes, depreciation, and amortization] and earnings in 2011."[16] In layman's terms, Olin expected the acquisition to produce profits immediately. In part that is because "SunBelt currently has the lowest cash manufacturing costs in the Olin system."[17] Even when later in the year it appeared the volume of chlorine shipments might be lower than expected, Olin was not worried. Entering the fourth quarter of 2011, Joseph D. Rupp, Chairman, President, and CEO of Olin Corporation, reassured investors that "[c]hlorine and caustic soda shipments are forecast to be lower than the fourth quarter of 2010 levels but will be more than offset by higher selling prices."[18]

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15 Comments of John E. Fischer, Senior Vice President & Chief Financial Officer, and Larry P. Kromidas, Assistant Treasurer & Director, Investor Relations, Olin Corporation, Wells Fargo Securities Conference (May 10, 2011) (attached as Exhibit 6).

16 *Id.*

17 *Id.*

18 "Olin's CEO Discusses Q3 2011 Results," Earnings Call Transcript (Oct. 28, 2011) at 2 (attached at Exhibit 7).

## III. Railroads Should Have Discretion to Adopt Bona Fide Operational Measures Aimed at Enhancing the Safety and Security of TIH Transportation

Having found that common carrier obligation requires railroads to transport TIH chemicals virtually anywhere on the Nation's rail network that shippers choose to send them, *see Union Pacific R.R. — Petition for Declaratory Order*, STB Finance Docket No. 35219 (served June 11, 2009), it is important that the Board apply other aspects of its regulatory framework in a manner that permits railroads to adopt reasonable measures to address the risks that TIH transportation entails. A recent Harvard report observed that "[t]he current regulatory scheme [at the Board] means that the risks of carrying a product that could cause billions of dollars in damage and impose potentially huge liability on a railway in the event of a release are rarely reflected adequately in rail transportation rates."[19] The report went on to conclude that "[p]olicy solutions should recognize the risk of TIH carriage as an externality, and should aim to incorporate external costs into the cost of TIH products and their transportation."[20]

Railroads should be permitted to give shippers incentives to consider the externality costs associated with TIH transportation when they decide to demand such transportation, an issue presented in a pending declaratory order proceeding (Finance Docket No 35504). Railroads should also be able to seek full compensation for the risks imposed on them when shippers demand such transportation. And, equally important, when shippers demand that railroads transport TIH commodities, railroads should have

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19 *See* Lewis M. Branscomb, et al., *Rail Transportation of Toxic Inhalation Hazards: Policy Responses to the Safety and Security Externalities*, Harvard Kennedy School, at 14-15 (Feb. 2010) (attached as Exhibit 8).

20 *Id.* at 63.

the flexibility to adopt operating practices designed to ensure that the mandatory transportation is carried out in a safe and secure manner.

NS does not have a position on the reasonableness of the specific operating rules adopted by RailAmerica for the handling of TIH shipments on its lines. But NS does urge the Board to make clear that railroad operating personnel on the ground are in the best position to make decisions about how to transport TIH chemicals in a safe and secure manner. Those are the personnel who have the necessary expertise and familiarity with local operating conditions to make sensible decisions that protect the safety of railroad employees and the communities railroads traverse. Accordingly, operating rules adopted for the purpose of addressing bona fide safety and security concerns should be presumed reasonable when they reflect the railroad's sound application of operating judgment. Indeed, in a contemporaneous proceeding shippers and their representatives parties are arguing that railroads should be encouraged to improve "the safety of the rail system." STB Finance Docket No. 35504, Opening Comments of CF Industries at 15. As they note, "[o]nly the railroad . . . can anticipate and detect and limit or mitigate damage from acts of third parties or acts of nature." STB Finance Docket No. 35504, Opening Comments of ACC et al. at 13.

Railroad operating discretion is not unlimited. Operating rules that are not promulgated out of a bona fide concern about safety or security, but instead are implemented *for the purpose* of deterring shippers from shipping by rail, might be deemed unreasonable. Likewise, railroads should be able to explain why, in their judgment, a particular rule reflects an appropriately measured rules approach for dealing with safety and security concerns in the applicable circumstances. But the presumption ought to be in favor of the railroad, with shippers required to prove that a particular rule or practice was adopted without an evaluation of the available alternatives or for the purpose of deterring shipments rather than out of legitimate safety or other concerns.

In particular, railroads should not have to prove the "cost-effectiveness" of the safety measures they adopt, as some commenters urge. To be sure, railroads may appropriately be required to explain why, in their judgment, a particular rule will in fact improve safety or security. But they should not have to provide any quantification of the specific "safety costs" that are saved as compared to the potential operating costs borne by the railroad (or shipper) in order to achieve improvements in safety and security. Railroads already have strong incentives to avoid imposing unnecessarily onerous operating measures on their own networks, which could cripple network performance and potentially even prove counter-productive from the standpoint of safety. Railroads likely will reach varying judgments on these issues, befitting their different circumstances.[21]

Moreover, although certain commenting parties would like for the analysis to hinge on a cost-benefit analysis of the railroads' proposed safety measure, it is clear that the federal government does not presently believe that the correlation must be particularly close to justify TIH-related transportation safety measures. In enacting a requirement that railroads develop, install, and operate a positive train control system on lines

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[21] Measures that might improve safety on a low-density branch line (such as a TIH-specific speed restriction or a limit on the number of TIH cars per train) might well have adverse efficiency and perhaps safety consequences if adopted on NS's busy network. As the Board noted in a recent decision, for example, BNSF applies an advance notice requirement at lesser-used interchange points that it does not apply at more heavily staffed facilities. *See Canexus Chemicals Canada L.P. v. BNSF Ry.*, STB Docket No. NOR 42131 (served Feb. 8, 2012).

carrying TIH commodities, the government acknowledged that the cost of implementing the system outweighed the benefits by a factor of 20 to 1.[22]

## IV. NEITHER EXISTING SAFETY REGULATIONS NOR THE *CONRAIL* CASE IS AN OBSTACLE TO OPERATING RULES DESIGNED TO ENSURE THAT TIH COMMODITIES ARE TRANSPORTED SAFELY AND SECURELY

To be sure, rail operations must comport with all applicable federal safety requirements, of which there are many. But those requirements merely set the floor, and the Board has routinely upheld railroad actions that supplement federal safety requirements. *See, e.g., Granite State Concrete Co., Inc. & Milford-Bennington R.R. v. Boston & Maine Corp. & Springfield Terminal Ry.*, STB Docket No. 42083 (served Sept. 24, 2004) (approving reasonableness of safety precautions not mandated by FRA rules). NS, for example, has adopted an array of operating rules that address safety issues not covered by federal regulations. Those rules, from mainline speed restrictions to yard operating practices, have evolved over decades of experience to take account of NS's own experiences and operating circumstances.

The *Conrail* decision, which upheld an ICC decision declining to approve a tariff for the transportation of nuclear materials that incorporated special train service,[23] is not an obstacle to measures aimed at improving the safety and security of TIH transportation for two reasons. First, *Conrail* arose under a statutory regime that placed the burden on the railroad to justify its rates predicated on special train service. That regime no longer

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22 76 Fed. Reg. 52922 (Aug. 24, 2011) ("FRA's cost benefit analysis of the PTC rule indicates that the railroads will incur approximately $20 in PTC costs for each $1 in PTC safety benefits."). NS does not believe the government should be adopting legislation or rules that have a cost-benefit ratio such as the one for PTC. NS only points it out to show that at least currently the standard set by the government indicates a willingness to require safety and security measures that far outweigh the calculable benefits.

23 646 F.2d at 650, 656.

exists, and railroads now have discretion to establish tariff terms and other rules that address rail transportation issues and those rules must only be reasonable – not perfect. Second, unlike the nuclear regulatory regime at issue in *Conrail*, the federal safety and security regulations governing the transportation of TIH chemicals expressly contemplate rail carriers taking complementary and supplementary actions.

**a. The Board Has Previously Found that *Conrail* Was Decided Under a Statutory Regime that No Longer Exists.**

The Board has already found that the *Conrail* case arose under a statutory scheme that no longer exists. *Conrail* addressed the ICC's investigation of Conrail's proposed tariff rate, which had been predicated on special train service. That context placed the burden squarely on Conrail to justify its proposed tariff. As the Board has observed, "[t]he *Conrail* decision was premised on facts not present here and on a statutory scheme predating the Staggers Act." *North American Freight Cars v. BNSF Railway Co.,* STB Docket No. 42060 (Sub-No. 1) (Jan. 26, 2007) ("*North American Freight Cars*"). In particular, *Conrail* arose "under a pre-1980 statutory provision that expressly put the burden of proof on a carrier whose proposed rate change was suspended or put under investigation before it became effective. *See* 49 U.S.C. § 10707(e) (1980)." *Id.* at 5; *see also Car Demurrage Rules, Nationwide*, 350 I.C.C. 777 (1975) (asking whether railroads had met their burden of proof under Section 15(7)).

Today, by contrast, railroads are granted the statutory right to establish any tariff rates and rules they wish so long as they are reasonable, and in a complaint case the burden is always on the party challenging those rates and rules to prove that they are unreasonable. 49 U.S.C. § 10702; *North American Freight Cars* at 5; *City of Lincoln v. STB*, 414 F.3d 858, 862 (8th Cir. 2005). Carriers are also "able to change their rules in response to changing circumstances . . ." *Arkansas Electric Coop. Corp. – Petition for Declaratory Order*, STB Finance Docket No. 35305, at 11 (served Mar. 3, 2011). Congress did not set a standard for determining what makes a tariff term reasonable. Instead, "[w]hether a particular practice is unreasonable typically turns on the particular facts." *Capitol Materials Inc. – Pet. for Declaratory Order – Certain Rates & Practices of Norfolk S. Ry. Co.*, STB Docket No. 42068, at 6 (served Apr. 12, 2004); *see also WTL Rail Corp. Petition for Declaratory Order & Interim Relief*, STB Docket No. 42092 (served Feb. 17, 2006). Unlike in *Conrail*, then, a rule will be held unlawful only if the party seeking relief establishes that the challenged practice is an unreasonable exercise of the railroad's discretion.

### b. FRA, PHMSA, and TSA Extensively Regulate Rail Safety for Transporting TIH/PIH, But Also Explicitly Set Only the Floor for Safety Measures.

Second, *Conrail* is premised on different facts than those applicable to TIH transportation. *Conrail* presented a "special situation" where "Congress ha[d] determined that the proper balance between adequate safety on the one hand, and promotion of nuclear energy on the other, should lie primarily with the NRC, not with other federal agencies, the states, or the railroads." *Conrail*, 646 F.2d at 648-49; *see also Northern States Power Co. v. Minnesota*, 447 F.2d 1143, 1153-54 (8th Cir. 1971), *aff'd mem.*, 405 U.S. 1035 (1972) ("Congress vested the AEC (now NRC) with the authority to resolve the proper balance between desired industrial progress and adequate health and safety standards.").[24]

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[24] Part of the balance struck by Congress in the nuclear field, of course, involves express limitations on potential liability for participants in the nuclear materials supply chain. *See Classification Ratings of Chemicals, Conrail*, 3 I.C.C.2d 331, 335 (1986) (when "the

The comments of ACC and Dow Chemical Company correctly point out that the regulatory regime constructed by FRA, TSA, PHMSA, and others regarding the transportation of TIH commodities provides incentives for railroads to be safe and mandate extensive safety rules.[25] In the ACC's words, "the regulations governing the rail transportation of TIH commodities are comprehensive and have been developed over a nearly 100 year period."[26] Whether that is the appropriate time-period or is a bit of verbal excess,[27] there is an extensive regulatory regime that governs routing, the exchange of cars between customers and railroads and between railroads, how railcars must be attended, where TIH cars may be placed in a train, the control system that must be installed by 2015, and much more.[28]

However, unlike in *Conrail*, where Congress made the judgment that the NRC would strike a "balance" between safety and "promotion of nuclear energy," safety regulations governing TIH transportation in many cases expressly set only a *floor* for railroad safety precautions. They are not a ceiling. For example, FRA and PHMSA expressly have stated that "parties are encouraged to go beyond the minimum regulatory requirements in establishing and implementing plans, rules, and procedures for safe

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transportation of nuclear materials is involved, the Commission has relied on the extensive safety regulation by both DOT and [Nuclear Regulatory Commission] and the limitation on a carrier's liability under the Price-Anderson Act"). Railroads have no such statutory protection as to TIH transportation.

25 Opening Evidence of ACC, STB Finance Docket No. 35517 at 4 (filed Jan. 13, 2012); *see also* Opening Evidence of Dow Chemical Co., STB Finance Docket No. 33517 at 11-14 (filed Jan. 13, 2012).

26 Opening Evidence of ACC, STB Finance Docket No. 35517 at 4 (filed Jan. 13, 2012).

27 Norfolk Southern cannot tell because ACC cites no authority for its "100 year" proposition.

28 *See e.g.*, 49 C.F.R. Parts 171-180; 49 C.F.R. Parts 200-244; 49 C.F.R. § 1580; The Rail Safety and Improvement Act of 2008, Pub. L. No. 110-432, Sec. 104(a), 122 Stat. 4848, 4856-57 (enacted Oct. 16, 2008) (requiring Positive Train Control PTC installation).

transportation operations." 74 Fed. Reg. 1793 (Jan. 13, 2009). Similarly, PHMSA routing rules set forth "the *minimum* criteria a rail carrier must consider in analyzing each route and alternative route." 75 Fed. Reg. 20762 (Apr. 16, 2008) (emphasis added). In other instances, the rules specifically delegate to the railroads substantial discretion to determine the best practices and procedures to comply with the basic tenants of the rule. For example, TSA expressly stated that it was leaving discretion to implement to the railroads: "Moreover, to allow freight railroad carriers a maximum degree of flexibility in adopting and implementing procedures to meet the car attendance performance standard, this section does not specify a maximum number of rail cars permitted per attending employee (or authorized representative) or define how close that individual must be to the rail car while attending it." 71 Fed. Reg. 76873 (Dec. 21, 2006). Thus, it is clear that although the myriad of FRA, PHMSA, TSA and other rules clearly impose a safety and security regime on railroads with which they must at a minimum comply, that regime provides railroads the option to establish higher levels of safety and security independently or as a means of implementing the regulations.

Finally, shipper groups rely heavily in this proceeding – rightly or wrongly – on the fact that there is a web of regulation governing rail transportation of chlorine and other TIH shipments.[29] Accordingly, shippers should be estopped from arguing elsewhere that railroads do not – or would not after a rule change – have a sufficient incentive to transport chlorine or other TIH commodities safely.[30]

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[29] Opening Evidence of ACC, STB Finance Docket No. 35517 at 4 (filed Jan. 13, 2012); *see also* Opening Evidence of Dow Chemical Co., STB Finance Docket No. 33517 at 11-14 (filed Jan. 13, 2012).

[30] ACC and other TIH shippers argue in STB Finance Docket No. 35504 that placing some liability on manufacturers and users of TIH and PIH through an indemnification provision in a

## CONCLUSION

The Board should address the tariff terms at issue in this proceeding in a manner that takes one incremental step towards allowing railroads the flexibility they need to address the extraordinary risks imposed on them by the obligation to transport TIH commodities on demand. The Board should (a) make clear that railroads have discretion to adopt safety measures in connection with the transportation of TIH commodities, and (b) impose on complainants the burden of proving that RailAmerica's tariff terms are outside of that broad zone of reasonableness.

Respectfully Submitted,

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Dated: February 27, 2012

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rail tariff will undermine a railroad's incentive to transport TIH in a safe manner. *See, e.g*, ACC Comments, STB Finance Docket No. 35504 at 13 (filed Jan. 25, 2012); CF Industries, Inc. Comments, STB Finance Docket No. 35504 at 15 (filed Jan. 25, 2012). The reliance here by ACC on the federal regulatory regime imposing incredibly detailed and specific requirements on railroads transporting these commodities undermines ACC's argument in that other proceeding. ACC cannot have it both ways.

**CERTIFICATE OF SERVICE**

I, Anand Viswanathan, certify that on this date a copy of the Reply Comments of Norfolk Southern Railway Company, filed on February 27, 2012, was served by email or first-class mail, postage prepaid, on all parties of record.

Anand Viswanathan

Dated: February 27, 2012

**STB Finance Docket No. 35517**

**CF INDUSTRIES, INC. v. INDIANA & OHIO RAILWAY COMPANY, POINT COMFORT RAILRWAY COMPANY, and MICHIGAN SHORE RAILROAD, INC.**

**REPLY COMMENTS**
**OF**
**NORFOLK SOUTHERN RAILWAY COMPANY**

# EXHIBIT 1

# TOXIC WARFARE

Theodore Karasik

Prepared for the United States Air Force
Approved for public release; distribution unlimited

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Project AIR FORCE

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# PREFACE

Recent events suggest that "toxic warfare"—or the use of inexpensive chemicals and industrial waste in weaponry—is on the rise. Accordingly, this report offers an initial analysis of the extent of the problem by bringing together what is currently known about toxic weapon use. Both state and nonstate actors (including insurgents and terrorists) are using toxic weapons, which provide an attractive asymmetrical option because they are inexpensive, are available in large quantities, are found in urban areas, and, perhaps most significantly, are not entirely secure from theft or diversion. The substances used to make these weapons have thus far been relegated to low-priority status under international law regulating the use of chemical weapons—thereby making it easier for those interested in their use to gain access to them. This report offers historical examples, most drawn from the past decade, to illustrate where and how such weapons have been used. It also examines U.S. operations during toxic warfare and discusses current thinking in the United States about toxic weapons with respect to both military operations and homeland security.

The report should be of interest to those involved in military and civilian crisis response planning. This study was conducted as part of the Strategy and Doctrine Program of RAND's Project AIR FORCE. Comments are welcomed and may be addressed to the author or to the Program Director, Dr. Ted Harshberger. The cutoff date for this research was January 2002.

## PROJECT AIR FORCE

Project AIR FORCE, a division of RAND, is the Air Force federally funded research and development center (FFRDC) for studies and analyses. It provides the Air Force with independent analyses of policy alternatives affecting the development, employment, combat readiness, and support of current and future air and space forces. Research is performed in four programs: Aerospace Force Development; Manpower, Personnel, and Training; Resource Management; and Strategy and Doctrine.

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## SUMMARY

In recent years, there appears to be an increased interest in weapons that incorporate chemicals and industrial wastes that are both inexpensive and relatively easy to acquire. Such "toxic weapons" provide a means for hostile state or nonstate actors to improve their capabilities within the context of asymmetrical warfare. In basic terms, toxic warfare refers to the use of chemicals or industrial waste to harm or alter the behavior of an opponent during military operations. Toxic warfare does not, however, require the use of traditional weapons; it can also involve the release of chemicals into the environment (e.g., from industrial manufacturing or waste sites). A preliminary review of incidents involving toxic weapons suggests that such weapons merit greater attention as part of military and civilian crisis response planning.

### WHAT ARE TOXIC WEAPONS?

In contrast to chemical weapons, which involve the use of banned substances such as the nerve agents sarin and soman, toxic weapons are made from materials that are usually readily (and legally) available in connection with industrial operations. The most common types of hazardous materials used in toxic weapons are irritants, choking agents, flammable industrial gases, water supply contaminants, oxidizers, chemical asphyxiants, incendiary gases and liquids, industrial compounds, and organophosphate pesticides. Various forms of toxic waste (e.g., petroleum spills, smoke, refuse, sewage, and medical waste) can also be used in toxic warfare.

Abundant sources of industrial materials and waste are available for use in toxic warfare. Although large industrial facilities are an obvious source of concern, other common urban locations, such as airports, college laboratories, and even garden-supply warehouses, pose risks as well. Illegal chemical and toxic waste sites are another potentially significant source of toxic warfare materials.

Toxic warfare can be used by both state and nonstate actors to achieve a number of objectives. Toxic warfare can cause casualties among opposing militaries by incapacitating and, in some cases, killing the adversary. Toxic warfare can also halt or force delays in military logistics flows or operations and can disrupt the functioning of the urban infrastructure through contamination or corrosion. Toxic weapons can, moreover, derive power from the uncertainty that stems from their potential use. Toxic substances often represent an unknown threat, and the level of uncertainty surrounding the potential damage these substances *might* cause can increase their impact even when little or no physical harm has been done.

## RECENT USE OF TOXIC WEAPONS

There have been many incidents of toxic warfare in recent years. During the Gulf War, retreating Iraqi forces intentionally caused the release of crude petroleum from field production facilities and ignited the oil to slow advancing coalition forces—the only time U.S. operations have faced a toxic attack. During the Balkan wars, Serbian forces attacked a Croatian Petrochemia facility that stored large quantities of anhydrous ammonia and a variety of other potentially hazardous chemicals. From 1993 to 1995, the facility was attacked six times with rockets, bombs, artillery, and mortars. Serbian forces also intentionally targeted a pesticide production facility at Sisak and a natural gas refinery in Ivanic. During the siege of Muslim forces in Tuzla by the Serbs, the Muslims threatened to release large quantities of chlorine gas from railroad tank cars under their control despite the large number of friendly casualties that would have resulted. Other toxic incidents have occurred in Chechnya, Sri Lanka, and the Middle East.

Some new trends in toxic warfare also seem to be emerging. For example, toxic weapons seem to be used more frequently in conjunction with increasingly complex forms of organization, training, and equipment, including that represented by Al-Qaeda and Osama bin Laden. Another trend concerns increased opportunism in the use or combination of toxic substances. Those who use toxic weapons seek to create uncertainty by exploiting whatever opportunities are available to bend the definition of chemical warfare and conventional conflict through their choice of toxic materials and tactics.

## TOXIC THREATS IN EXPEDITIONARY SETTINGS

Although U.S. military forces have not yet faced repeated threats from toxic weapons, that possibility clearly exists, particularly in light of the wide availability of toxic materials. One such threat arises from toxic smoke in the field of operations, which can be used to cause confusion, impair vision, and disrupt military operations. Water supplies in areas of operations are vulnerable to both intentional and accidental contamination. Toxic waste poses another threat. The U.S. military is currently seeking to improve its ability to respond to toxic warfare by updating military field manuals and related documents to address the issue of organizing, training, and equipping for such warfare.

At the same time, however, the level of threat that toxic weapons represent remains to be determined. Should toxic warfare be considered a mere nuisance or a threat of strategic concern? Although it is impossible to know how extensively toxic weapons will be used in the future, there are several reasons for concluding that toxic warfare merits serious consideration as part of future planning strategies.

- **The United States is not immediately aware of the location of toxic threats.** In future operations, it is possible that an entire area of operations could be contaminated with toxic waste. Although the identification of specific threats is a painstaking process, U.S. forces will need to improve their knowledge of the locations of both legal and illegal sources of toxic waste.
- **At the operational level, U.S. forces currently have no tailored response to toxic warfare in doctrine.** In particular, the U.S. military will need to resolve at the doctrinal level the trade-off between force protection and mobility/agility. Put another way, to what extent does the potential for toxic warfare require that chemical kits, protective clothing, cleanup materials, and the like

be carried on operations if doing so would impede the mobility and agility of the forces?

- **The use of toxic weapons has implications for U.S. military lift and logistics.** As base security becomes more critical to operations, the vulnerability of key logistics sites has emerged as an important issue. Many sites are vulnerable to toxic attack, including ports, airfields, and related fixed sites that serve as choke points. Support staging areas as well as rail and road networks are also potential targets, as are intermediate and infrastructure logistics bases. Procedures will be needed to address these threats.
- **At the tactical level, U.S. armed forces may not be ready for toxic warfare.** The Office of the Secretary of Defense has found a number of problems associated with preparation for toxic warfare as a subset of a nuclear, biological, or chemical attack. For example, toxic vapors often hug the ground, an issue that is not addressed in some scenarios. Air Force programs also require additional policy and guidance, an integrated training and exercise program, and first-responder equipment for addressing toxic attacks.
- **Cleanup from a toxic attack may pose a difficult challenge.** The decontamination of aircraft presents an especially difficult challenge, as demonstrated by the oil-laden rain encountered by coalition forces during the Gulf War. Decontamination procedures will need to address fixed sites as well as cargo and equipment.

## TOXIC THREATS IN THE UNITED STATES

Toxic warfare is a threat not just for U.S. forces engaged in military operations but also for civilians within the United States. This risk is increased by the wide availability of toxic materials throughout the United States, together with the proximity of industrial operations to large urban centers.

At the forefront of toxic warfare in the United States are the first responders, whose mission is to respond immediately in the event of a crisis or disaster. First responders include personnel from medical, law enforcement (or security), fire/rescue, hazardous material

(HAZMAT), and explosive ordnance disposal organizations. U.S. domestic responders are in the process of organizing, training, and equipping to counter potential attacks.

Other domestic capabilities, however, need to be improved as well. Currently, for example, there is no consistent approach toward burden sharing among agencies, particularly with regard to treating casualties. Internet connectivity in many hospitals remains poor, with only 25 percent of laboratories up to federal standards for access to and dissemination of information. Moreover, in the event of multiple toxic attacks, the scope of response needed could overwhelm local resources.

Military and civilian crisis response preparedness efforts must also be better coordinated. The U.S. military possesses chemical weapon prevention and cleanup expertise that is applicable to homeland security. Civilian crisis response personnel can for their part provide expertise in areas such as HAZMAT. Additional opportunities to share information and coordinate efforts need to be identified.

Finally, the risks associated with toxic warfare—both for expeditionary forces and within the United States—must be better understood. Planning for military operations and civilian crisis response requires a detailed understanding of the benefits and costs associated with various options for countering toxic weapons. While this report is meant to fill some of the gaps in understanding surrounding toxic weapons, a quantitative risk assessment should be considered as a means of providing a more thorough evaluation of the problem.

# ACKNOWLEDGMENTS

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# ACRONYMS

| | |
|---|---|
| AFMIC | Armed Forces Medical Intelligence Center |
| APOD | Aerial port of debarkation |
| $C^2$ | Command and control |
| $C^4I$ | Command, control, communications, computers, and intelligence |
| CBRN | Chemical, biological, radiological, and nuclear |
| CBW | Chemical and biological weapon |
| CINC | Commander in chief |
| CONUS | Continental United States |
| CWC | Chemical Weapons Convention |
| ELN | Army of National Liberation (Colombia) |
| EOD | Explosive ordnance disposal |
| FAE | Fuel air explosive |
| FARC | Revolutionary Armed Forces of Colombia |
| FM | Field Manual |
| HAZMAT | Hazardous material |
| HQ AFCESA | Headquarters, Air Force Civil Engineer Support Agency |

| | |
|---|---|
| IO | Information operations |
| JP | Joint Publication |
| KTO | Kuwaiti theater of operations |
| LPG | Liquefied petroleum gas |
| LTTE | Liberation Tigers of Tamil Eelam |
| MIC | Methyl isocyanate |
| NBC | Nuclear, biological, and chemical |
| OSD | Office of the Secretary of Defense |
| PCB | Polychlorinated biphenyl |
| PKK | Kurdish Workers Party |
| POE | Port of embarkation |
| PSYOP | Psychological operations |
| SBCCOM | Soldier and Biological Chemical Command (U.S. Army) |
| TRANSCOM | Transportation Command |
| UNPROFOR | United Nations Protection Force |
| USACMLS | U.S. Army Chemical School |
| WMD | Weapons of mass destruction |

Chapter One

# INTRODUCTION

In recent years, there would appear to be an increased interest in weapons that incorporate inexpensive, relatively easy-to-acquire chemicals and industrial wastes. Such "toxic weapons" might take the form of a rocket containing insecticide or several barrels of toxic chemicals left in an adversary's path to force the diversion of troops. To date, however, instances of toxic warfare have not been subjected to extensive analysis, largely because greater interest has been manifested in more sophisticated forms of chemical warfare, including the use of weapons of mass destruction (WMD) and the development of nuclear, biological, and chemical (NBC) doctrine.[1]

A preliminary review of incidents involving toxic weapons suggests that they merit greater attention, especially because of the threat they pose within the context of asymmetrical warfare. Asymmetrical strategies focus on attacking an adversary's points of vulnerability by

[1]See Jean Pascal Zanders, "Assessing the Risk of Chemical and Biological Weapons Proliferation to Terrorists," *Nonproliferation Review*, Fall 1999, pp. 17–34; Raymond A. Zilinskas, "The Threat of Bioterrorism," Center for Nonproliferation Studies briefing, August 3, 1998, available at http://cns.miis.edu/iiop/cnsdata; Al J. Venter, "Biological Warfare: The Poor Man's Atomic Bomb," *Jane's Intelligence Review*, Vol. 11, No. 3, March 1, 1999, p. 42; Malcolm Dando, "Discriminating Bio-Weapons Could Target Ethnic Groups," *International Defense Review*, Vol. 30, No. 3, March 1, 1997, p. 77; Gert G. Harigel, *Chemical and Biological Weapons: Use in Warfare, Impact on Society and Environment*, Carnegie Endowment for International Peace, available at http://www.ceip.org/files/publications/Harigelreport.asp?p=8; *Chemical Warfare: A Burning Issue—Project on Insurgency, Terrorism and Security*, available at http://paladin-san-francisco.com/libgas03.htm; Jonathan B. Tucker (ed.), *Toxic Terror: Assessing Terrorist Use of Chemical and Biological Weapons*, Cambridge, MA: MIT Press, 2000; and Graham Spearson, "Strategic and Security Issues: Forbidden, Not Forgotten," *International Defense Review*, Vol. 30, No. 3, March 1, 1997, available at Intelink.

increasing the level of threat in areas in which that adversary is least prepared. Asymmetrical tactics seek means of catching the enemy off guard, and they do so using unexpected—as well as typically inexpensive and easily available—means of attack.

Toxic weapons provide an opportunity for hostile state or nonstate actors to increase their asymmetrical capabilities. The materials for toxic warfare are ubiquitous, particularly in industrialized nations such as the United States. The number of such attacks seems to be on the increase, and the potential exists for more frequent and more lethal uses of such weapons in the future. This risk can increase to the extent that U.S. troops are deployed to unstable, unsafe areas in which toxic materials are readily available.

This study attempts to fill some of the gaps in our understanding of toxic weapons in asymmetrical warfare. Toward this goal, it first examines the scope of the risks these weapons pose. It then describes some recent incidents involving toxic warfare and proceeds to discuss the nature of the risk both to U.S. expeditionary forces and to the U.S. homeland.

## RECENT EXAMPLES OF TOXIC WARFARE

The manner in which industrial chemicals may be intentionally used as toxic weapons can be briefly illustrated through some examples drawn from the Gulf War and the Balkan conflict. In 1990, retreating Iraqi forces intentionally caused the release of crude petroleum from field production facilities and ignited the oil in efforts to slow advancing coalition forces. In the mid-1990s, the Balkan conflict involved frequent attacks on chemical production facilities. From 1993 to 1995, for example, Serbian forces launched six attacks on a Petrochemia facility near Kutina, Croatia, that stored large quantities of anhydrous ammonia as well as a variety of other potentially hazardous chemicals; these attacks involved rockets, bombs, artillery, and mortars. Serbian forces are also known to have targeted a pesticide production facility at Sisak and a natural gas refinery in Ivanic. Although none of these attempts was wholly successful, subsequent U.S. modeling efforts indicated that if the attacks had destroyed existing stored chemical containers, lethal concentrations of chemicals would likely have spread over a wide area. Toxic weapons were also used against the Serbs, such as when Muslim forces in

Tuzla threatened the use of chemicals in efforts to hold off a Serbian attack against the city. These forces vowed to release large quantities of chlorine gas from railroad tank cars if the city was assaulted—despite the large number of friendly casualties that would have resulted from such an action.

## THE UBIQUITY OF RAW MATERIALS FOR TOXIC WEAPONS

Although the threat posed by toxic weaponry may in some cases be little more than a nuisance, in other cases it can have catastrophic results. Indeed, the fact that some acts of toxic warfare have been ineffective should not be used as evidence that the threat from these weapons is low, especially in light of the ubiquity of toxic substances both within the United States and worldwide. The relatively easy access to such materials, when combined with their low cost and the low security often associated with storage facilities, makes them a potentially attractive and highly available option for asymmetrical warfare. Industrialized nations are home to thousands of facilities and sites that manufacture, use, or transport toxic substances; these include oil and gas installations, extended pipelines, refineries, and chemical shipping facilities.[2] At the same time, chemicals useful for toxic warfare can be obtained almost anywhere in the world. Existing stored chemicals—including those found on military sites—can easily be made to serve as "weapons of opportunity."

The notion of opportunism is central to this discussion. A manufacturing capability is not required in order for industrial chemicals to be used as weapons. In fact, these substances need not even be shaped into anything resembling a traditional weapon in order to be effective. In some cases, toxic warfare could occur as a "side effect" of more traditional military operations, such as when damage to industrial facilities from military operations leads to a catastrophic chemical release. Indeed, the very presence of such facilities can threaten military operations in urban areas, which could be affected if, for example, an electrical power interruption or an improper facility shutdown were to cause a chemical release. Such events are common during complex emergencies, armed conflicts, and post-

[2]See "Forced to Take a Lead on Hazardous Materials," *Jane's International Police Review*, January 1, 2000, available at Intelink.

conflict reconstitution periods. The key point is that while toxic warfare is typically initiated by a deliberate act, it can also result when adversaries exploit the opportunities presented by accidental toxic releases and the ubiquity of toxic substances.

## THE IMPACT OF TOXIC WEAPONS

Toxic warfare is used by state and nonstate actors to achieve military and political goals. On one level, toxic warfare can cause casualties among opposing militaries. It can incapacitate and in some cases kill the adversary, although the latter objective is not necessarily the primary motivation for its use. Toxic warfare can also halt or force delays in military logistics flows or operations. Similarly, it can disrupt the functioning of the urban infrastructure and create panic among the citizenry. Yet much of the power of toxic weapons lies in the uncertainty associated with their potential use. Toxic substances often represent an unknown threat, and the level of uncertainty surrounding the potential damage these substances *might* cause—be it to soldiers in transit, to the civilian population, or to urban infrastructure and military logistics—can increase their effect even in cases in which little or no physical harm has occurred. Thus, while more conventional types of weapons might cause greater levels of collateral damage and can be more accurately targeted, toxic weapons are useful in asymmetrical warfare precisely because they use relatively small amounts of available chemicals or industrial waste to create what seems to be—and sometimes is—a disproportionately large and potentially devastating threat.

Toxic warfare remains a possibility within the United States in large part because of the size of the U.S. industrial infrastructure, which makes greater use of toxic chemicals and produces more industrial waste than any other country in the world. The quantity of chemicals alone provides terrorists with many potential opportunities to use toxic weapons to scare, maim, and kill. The possibility of toxic warfare is especially likely during complex emergencies and conflict.

## ABOUT THIS REPORT

This study provides a qualitative overview of the threat posed by toxic weapons and identifies key vulnerabilities faced by the United

States and the U.S. military, particularly the U.S. Air Force. Because the analysis is drawn entirely from unclassified sources, it cannot offer a detailed analysis of the intelligence requirements for toxic warfare. Nor does the report seek to provide a quantitative assessment of the risks associated with toxic weapons. While such an effort may prove useful and even necessary in helping the U.S. military determine how great an effort should be directed toward toxic weapons, it was beyond the scope of this study.

The remainder of the report focuses on several issues related to toxic warfare. Chapter Two explains the composition and sources of toxic weapons as well as their potential for harm. Chapter Three analyzes the use of toxic weapons by state and nonstate actors over the past decade and considers the potential for escalated use. Chapter Four focuses on the threat to U.S. forces that are engaged in expeditionary operations, particularly the U.S. Air Force. Finally, Chapter Five considers the nature of the threat to the U.S. homeland.

# WHAT ARE TOXIC WEAPONS?

If we are to analyze the potential threat toxic weapons pose, we must first look in more detail at the nature of toxic weapons, the sources of materials for those weapons, and the type of damage they can cause. This chapter addresses each of these issues in turn.

## THE COMPONENTS OF TOXIC WARFARE

Put simply, toxic warfare refers to the use of chemicals or industrial waste to harm or alter the behavior of an opponent during military operations.[1] Toxic warfare does not require the use of weapons per se; while toxic substances may be incorporated into traditional weaponry, such warfare can also involve the release of chemicals into the environment (e.g., from industrial manufacturing or waste sites) without the use of any traditional weapons. Toxic warfare typically involves the use of inert chemicals that in some cases produce immediate, mild health effects. These conditions cannot, however, spread without direct exposure to the substances, which are relatively nonpersistent in the environment. In contrast to chemical weapons, which can involve the use of banned substances such as the nerve agents sarin and soman, toxic weapons are made from materials that are usually readily (and legally) available in connection with industrial operations.

[1]Dust agents are also part of toxic warfare in that toxic materials can absorb substances and carry the agent toward its intended target site depending on the time of day or night, the ground and air temperature, and weather patterns at the site of use.

Among the most common types of hazardous materials are the following:

- Irritants (acids, ammonia, acrylates, aldehydes, and isocyanates);
- Choking agents (chlorine, hydrogen sulfide, and phosgene);
- Flammable industrial gases (acetone, alkenes, alkyl halides, and amines);
- Water supply contaminants (aromatic hydrocarbons, benzene, etc.);
- Oxidizers capable of increasing the danger of explosions (oxygen, butadiene, and peroxides);
- Chemical asphyxiants (aniline, nitrile, and cyanide compounds);
- Incendiary gases (compressed isobutene, liquefied natural gas, and propane);
- Incendiary liquids (liquid hydrocarbons, gasoline, and diesel and jet fuel);
- Industrial compounds that act much like blister agents (dimethyl sulfate); and
- Organophosphate pesticides that can act as low-grade nerve agents.

Various forms of toxic waste (which may include petroleum spills, smoke, refuse, sewage, and medical waste) can also be used in toxic warfare. All these substances can contribute in varying degrees to a state or nonstate actor's asymmetrical capability.[2]

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[2]Joint Publication (JP) 3-11 defines industrial chemicals as chemicals developed or manufactured in industrial operations or research by industry, government, or academia. These chemicals are not primarily manufactured for the specific purpose of producing human casualties or rendering equipment, facilities, or areas dangerous for human use. Hydrogen cyanide, cyanogen chloride, phosgene, and chloropicrin are industrial chemicals that can also be military chemical agents. This term and its definition are approved for inclusion in the next edition of JP 1-02. See *Joint Doctrine for Operations in Nuclear, Biological, and Chemical (NBC) Environments*, Washington, D.C., Joint Publication 3-11, July 11, 2000.

The Chemical Weapons Convention (CWC) regulates the use of chemical substances in warfare, including more traditional chemical weapons as well as substances used to make toxic weapons. Article 2, paragraph 1, of the CWC defines "chemical weapons" as

> (a) Toxic chemicals and their precursors, except where intended for purposes not prohibited under this Convention, as long as the types and quantities are consistent with such purposes;
>
> (b) Munitions and devices, specifically designed to cause death or other harm through the toxic properties of those toxic chemicals specified in subparagraph (a), which would be released as a result of the employment of such munitions and devices; [and]
>
> (c) Any equipment specifically designed for use directly in connection with the employment of munitions and devices specified in subparagraph (b).

Many of the substances used in toxic weapons are found on Schedule 3 of the CWC.[3] While Schedule 1 of the CWC focuses on superlethal

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[3]Schedule 1 lists three families of nerve agents: the sarin, soman, and GF family; the tabun family; and the VX family. Nerve agents are organophosphorous chemicals of very high toxicity. The first nerve agent, tabun, was discovered in 1936 during a search for better pesticides. Nerve agents act by inhibiting the enzyme acetylcholinesterase, thus preventing the enzyme from destroying the neurotransmitter acetylcholine after it has transmitted a nerve signal to a muscle. The muscle will then remain contracted—i.e., in cramp. Few or no peaceful uses have yet been identified for any members of the three listed nerve agent families.

Schedule 1 includes two families of nerve agent precursors and two individual nerve agent precursor chemicals. Mustard agents and lewisites cause wounds resembling burns and blisters. They can also cause severe damage to the eyes, respiratory system, and internal organs. Schedule 1 includes 15 agents of this type: nine sulfur mustards, three nitrogen mustards, and three lewisites. Mustard gas was discovered in 1822 and was used extensively during World War I. In the 1930s it was used against Abyssinia and China and in the 1980s against Iran. A considerable part of the present-day stockpile of chemical weapons to be destroyed under the convention consists of mustard agent in bulk form and in filled munitions.

Two toxins have been included in Schedule 1: ricin and saxitoxin. Both have been studied for possible use as chemical weapons. Ricin is a protein that is formed in the seeds of the widely cultivated castor oil plant, from which it can be extracted. It is more toxic than nerve agents on a weight basis and acts by blocking the body's synweapons that involve nerve agents and Schedule 2 includes dual-use (both industrial and military) chemicals (typically of limited use), Schedule 3 focuses on chemicals that can be legally used in industrial processes. Schedule 3 chemicals tend to be easier to obtain than those listed in Schedules 1 and 2 and can be employed for destructive purposes. Typically they have also been less widely emphasized than those found in Schedules 1 and 2.

One of the greatest threats from Schedule 3 toxins comes when substances are combined. The result can be a weapon-grade substance such as phosgene, cyanogen chloride, hydrogen cyanide, and chloropicrin. Each of these chemicals has a legitimate industrial use but also poses a threat in toxic warfare. Phosgene is a gas used as an intermediate in the preparation of many organic chemicals, including agrochemicals, and was used in chemical weapons during World War I. Inhalation can be fatal, but exposure may not be noticed immediately. Cyanogen chloride and hydrogen cyanide are both important synthetic intermediates; hydrogen cyanide has also been used as a pesticide. Both can block cell respiration, and high concentrations can be fatal within minutes. Chloropicrin is a soil sterilant, grain

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thesis of proteins. Ricin is being studied as a possible chemotherapeutic agent for the treatment of leukemia and liver cancer. Saxitoxin is a complex organic chemical synthesized by a blue-green algae species. These algae provide food for mussels, which accumulate the toxin. The toxin acts on the nervous system. One milligram can eventually kill a human being. Higher doses may be lethal within 15 minutes. Saxitoxin is used as a biochemical research tool.

Schedule 2 agents are dual-use chemicals of limited use. There are three toxic chemicals. Amiton is an organophosphorous insecticide that was first synthesized around 1950. Today it is considered too toxic for use in agriculture. PFIB, short for perfluoroisobutylene, is a gas that is formed as a by-product during the production of some perfluorinated polymers, such as Teflon. It has no commercial application. Its toxicity is similar to that of phosgene (see below). BZ has earlier been weaponized as an incapacitating agent to be disseminated as aerosolized solid particles. It is widely used in minute quantities as a biochemical research tool and is also an intermediate in the production of a pharmaceutical. Finally, Schedule 2 includes a considerable number of precursors to nerve agents, mustard gas, lewisites, and BZ. All chemicals containing a phosphorus atom with one attached methyl, ethyl or propyl group are included (with *one exception: the pesticide fonophos).*

Schedule 3 includes phosgene (carbonyl dichloride), cyanogen chloride, hydrogen cyanide, and chloropicrin (trichloronitromethane). Precursors are phosphorus oxychloride, phosphorus trichloride, phosphorus pentachloride, trimethyl phosphite, triethyl phosphite, dimethyl phosphite, diethyl phosphite, sulfur monochloride, sulfur dichloride, thionyl chloride, ethyldiethanolamine, methyldiethanolamine, and triethanolamine.

disinfectant, and synthetic intermediate. Exposure can cause severe irritation and lacrimation.

Although Schedule 3 chemicals are not considered nerve agents either by international law or by chemical treaty, Schedule 3 includes seven nerve agent precursors. Examples include phosphorus oxychloride and phosphorus trichloride, which have extensive applications in the chemical industry, including insecticide production and chlorination. Three sulfur mustard and three nitrogen mustard precursors are listed on Schedule 3, including triethanolamine, which has several uses ranging from the production of surface-active chemicals to use as a solvent. Sulfur monochloride serves as a chlorinating agent in the production of dyes and pesticides and is also used for cold vulcanization of rubber and as a polymerization catalyst for vegetable oils.

As these examples suggest, toxic weapons can have lethal potential—although, as will be shown later, they need not be lethal in order to be effective.

## SOURCES OF TOXIC SUBSTANCES

One of the most important features of toxic weapons is the ready availability of the substances used to create them. There are abundant sources of industrial materials and waste for use in toxic warfare. In fact, chemical waste is likely to be found in some form and quantity at any industrial site. Unprocessed laboratory solvents, for example, pose a risk of toxic exposure, especially if they enter into the water supply. The risk of toxic exposure is significant because chemical production sources and stockpiles are frequently stored in drums and tanks located near inhabited areas. Industrial chemicals that are released as vapors can pose an additional risk because they tend to remain concentrated in locations downwind from the release point and can accumulate in low-lying areas such as valleys, ravines, and man-made underground structures. Table 2.1 lists the major industrial sources of chemical toxins.

While large industrial facilities are obviously sources of major concern for toxic weaponry, other common urban locations pose risks as well. Urban areas that contain toxic materials include airports, col-

**Table 2.1**

**Potential Sources of Chemical Toxins for State and Nonstate Use**

| |
|---|
| Paint formulation and organic chemical producers |
| Production of pesticides and wood preservatives |
| Manufacturing plants and smelting industries |
| Agricultural fumigants, industrial wastes, and pharmaceutical wastes |
| Lead, mercury, and cadmium-nickel battery manufacture |
| Textile mills, cosmetics manufacturing, dyeing and tanning industries |
| Petroleum refining |

SOURCE: George A. Alexander, "Ecoterrorism and Nontraditional Military Threats," *Military Medicine*, Vol. 165, No. 1, January 2000, p. 3.

lege laboratories, and even garden-supply warehouses.[4] The most common risks are associated with gases, especially the irritants chlorine, sulfur dioxide, ammonia, and hydrogen chloride. Table 2.2 shows the most common locations and sources of toxic materials in urban areas.

Another potentially major source of materials for toxic warfare lies in the illegal chemical and toxic waste sites—both industrial and medical—that can be found throughout North America, Europe, the Middle East, and likely East Asia. Millions of tons of toxic waste are transported each year by both organized and nonorganized criminal networks into poorer, urbanized centers in areas of conflict and crisis.[5] Because criminals seek to avoid waste disposal fees, they typically select remote areas to deposit their illegal toxic shipments, thereby making it easy for these materials to be diverted by state or nonstate actors for other uses—including military tactics and operations.[6] Increasingly, these wastes are being transported to

[4]Annual waste production is discussed in Gert G. Harigel, *The Concept of Weapons of Mass Destruction: Chemical and Biological Weapons, Use in Warfare, Impact on Society and Environment*, presented at the Conference on Biosecurity and Bioterrorism, Istituto Diplomatico "Mario Toscano," Rome, Italy, September 18–19, 2000, p. 10.

[5]See John Dean, "Organized Crime Versus the Environment," *Jane's International Police Review*, January 1, 2000, available at Intelink; and Christoph Hilz, *The International Toxic Waste Trade*, New York: Van Nostrand Reinhold, 1992.

[6]See "Forced to Take a Lead on Hazardous Materials," January 1, 2000; Mark Galeotti, "Crimes of the New Millennium," *Jane's Intelligence Review*, August 1, 2000, available

**Table 2.2**

**Locations of Toxic Materials in Urban Areas Available to State and Nonstate Actors**

| Location | Toxic Materials |
|---|---|
| Airports | Aviation gasoline, jet fuel |
| Farm and garden-supply warehouses | Pesticides |
| Barge terminals | Bulk petroleum and chemicals |
| College laboratories | Organic chemicals, radioactive material |
| Electronics manufacturers | Arsine, arsenic trichloride |
| Food processing and storage areas | Ammonia |
| Glass and mirror plants | Fluorine, hydrofluoric acid |
| Pipelines and propane storage tanks | Ammonia, methane, and propane |
| Plastic manufacturers | Isocyanates, cyanide compounds |
| Landscaping businesses | Ricin |
| Medical facilities | Radioactive isotopes, mercury, waste |
| Inorganic chemical plants | Chlorine |
| Hard rock ore mines | Potassium and sodium cyanide |
| Pesticide plants | Organophosphate pesticides |
| Petroleum storage tanks | Gasoline, diesel fuel |
| Photographic supply distributors | Cyanides, heavy metals |
| Rail and trucking lines, chemical manufacturing plants | Anhydrous ammonia; sulfuric, phosphoric, and hydrochloric acids; flammable liquids; chlorine; peroxides; and other industrial gases |
| Power stations and transformers | Polychlorinated biphenyls (PCBs) |

SOURCE: *The Infantryman's Guide to Modern Urban Combat*, Field Manual (FM) 90-10-1, Q-2 (coordinating draft), July 1, 2000 (hereafter referred to as FM 90-10-1).

unstable areas. In Somalia and in the Levant, for example, illegal toxic waste transfers measuring in the hundreds of tons occur alongside military operations.[7] Eventually the two may intersect, creating a toxic combat environment that affects the U.S. Air Force and other U.S. services.

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at Intelink; and Mark Galeotti, "The New World of Organized Crime," *Jane's Intelligence Review*, September 1, 2000, available at Intelink.

[7]The Israeli transfer to Jordan involved 500 tons of toxic material. See Ghassan Joha, "Israel's Bid to Dump Toxic Waste in Jordan Foiled," *The Star*, November 30, 2000, accessed from FBIS-IAP-20001130000091. For more on illegal toxic dumping, see Svend Soyland, *Criminal Organizations and Crimes Against the Environment: A Desktop Study*, Turin, Italy: United National Interregional Crime and Justice Research Institute, June 2000.

## THE IMPACT OF TOXIC WARFARE

There are three broad categories of effects associated with toxic warfare: health hazards, damage to or contamination of military or civilian infrastructure, and psychological effects resulting from the actual or threatened use of toxic substances.

In assessing the potential human health hazards or risks from exposure to toxic weapons, we must consider the form of the substance released (solid, liquid, or gas) as well as its innate toxicity and the nature of the exposure (e.g., how much of the chemical was released and whether the person was exposed through inhalation, ingestion, etc.).[8] For humans, the most extreme health effects typically occur as a result of exposure to gases. The irritants chlorine, sulfur dioxide, and hydrogen chloride all have relatively high toxicity when inhaled. In addition, combustibles such as the polymer intermediate vinyl acetate present extreme fire hazards. In the 1970s, the latter compound was responsible for a large, potentially dangerous vapor release in a major metropolitan area; the explosion involved a 30,000-gallon-capacity tank as well as 21 other tanks with chemical substances. The greatest threat to people comes from off-gases, which form from the oxidation of modern plastics and their monomers. Vinyl chloride, carbon monoxide, and hydrogen cyanide, for example, contribute to making phosgene upon burning. As many as half of the deaths attributed to smoke inhalation are actually due to poisonous off-gases released during fires.

The lethality of off-gases was apparent in the 1984 disaster in Bhopal, India, in which a disgruntled employee mixed water into methyl isocyanate (MIC), a chemical intermediate used in the synthesis of carbamate pesticide (sevin). The local inhabitants who gathered around the plant to watch the disaster unfold inhaled the deadly gases released from the mixture of water and MIC and were among the first of more than 3800 fatalities. Although most carbamate pesticides manufactured in Western countries today do not call for large vol-

[8]D. J. Rodier and M. G. Zeeman, "Ecological Risk Assessment," in L. G. Cockerham and B. S. Shane, *Basic Environmental Toxicology*, Boca Raton, FL: CRC Press, 1994, pp. 581–604; E. B. Overton, W. D. Sharpe, and P. Roberts, "Toxicity of Petroleum" in *Basic Environmental Toxicology*, pp. 133–156; and P. A. Reinhardt and J. G. Gordon, *Infectious and Medical Waste Management*, Chelsea, MI: Lewis Publishers, 1991.

umes of MIC on-site, MIC is typically transported to the sites during the production process. In addition, other chemicals that are typically kept on-site at Western industrial facilities (e.g., ammonia and phosgene) could potentially result in a catastrophic release of a magnitude similar to that of the Bhopal incident.[9] The impact of such catastrophic releases could involve thousands of individuals, resulting in health effects ranging from minor lung and skin irritation to death.

In addition to causing health effects, toxic substances can be used by state and nonstate actors against civilian and military symbols and infrastructure. Toxic warfare can render infrastructure targets unfit for occupation or use by humans and can also damage structures through corrosion. State and nonstate actors can use toxic warfare against civilian and military building and facilities, population centers, command-and-control ($C^2$) facilities, and logistical lines. Civilian targets include national monuments, public gathering places, conveyances, and energy and water facilities. Military targets include fixed formations such as bases or troop emplacements and mobile targets such as convoys, columns, and shipping. When used against military targets, toxic weapons can interrupt operations by forcing an opponent to change planning and deployment options on short notice. Other civilian and military targets include military bases, airfields, government and civilian buildings, oil and gas pipelines, pumping stations, refineries, and water supplies as well as transportation infrastructure such as highways and bridges.[10]

Toxic weapons also have the potential for use in psychological operations. The presence of toxic materials or even the possibility of their intended use can result in avoidance, uncertainty, fear, panic, and a host of other reactions in the population—even when the actual physical damage stemming from their use is limited. The extent

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[9]Derived from interviews with Monterey Institute of International Studies researcher Eric Croddy, 2000–2001.

[10]Water supplies provide an interesting example of the confusion that can result from understanding the difference between a biological and toxic attack. Although the commanders in chief (CINCs) treat water security with stringent security measures, an outright attack is difficult to assess, treat, and counter. See Al J. Venter, "Poisoned Chalice Poses Problems: The Terrorist Threat to the World's Water," *International Defense Review*, Vol. 32, No. 1, January 1, 1999, p. 57.

of psychological effects from toxic warfare is to a large extent unknown, and the unclassified sources reviewed for this report do not provide sufficient evidence to warrant many conclusions in this area. Given the potential for toxic weapons to cause serious harm, however, it is likely that even less toxic substances could be perceived as posing a potentially lethal danger—particularly when the composition of the substances used in such weapons is not known, as is often the case. It is likely that the uncertainty surrounding the use of many toxic weapons will play to the advantage of those who use them.

Such uncertainties are in fact a key feature of toxic weapons and constitute one of the reasons it is difficult to plan a response to their use. An individual act of toxic warfare could be lethal or could be a mere nuisance. Yet the extent of a toxic weapon's impact cannot always be known immediately or even for some time after an attack. For example, there is no question that a weapon incorporating medical waste would have a much smaller relative impact (e.g., five cases of HIV or hepatitis B or C) than a toxic release that killed thousands. Yet the extent of the harm caused by the biohazardous materials might not be immediately apparent, and if the number of cases of infected people gradually increased, fear and panic could spread among the populace. The impact of the weapon using medical waste would still not approach that of the toxic release. Nonetheless, the uncertainty surrounding the biohazardous weapon's effect could serve to enhance that effect and produce a significant result given the materials used.

In the next chapter, we will look at some examples of how toxic weapons have been used by both state and nonstate actors.

Chapter Three

# RECENT USE OF AND THINKING ABOUT TOXIC WEAPONS

As discussed in the previous chapters, toxic weapons offer a number of advantages to state and nonstate actors who seek to advance their military and political objectives. Industrial chemicals and chemical waste are both plentiful, providing a low-cost and easily assembled option that can be deployed through a variety of means—including air delivery (missiles and rockets), land delivery (cars, trucks, or containers in legal or illegal transit or at a stationary location), or sea delivery (barges and small craft). Toxic weapons can cause physical harm to humans and can damage and contaminate infrastructure. They can also create temporary panic or chaos, thereby exerting an asymmetrical effect on information and psychological operations (IO/PSYOP). The advantages of toxic weapons are offset somewhat by the uncertainty surrounding their effects; these weapons are often difficult to target, and their physical impacts can be inconsistent. Such uncertainties, however, can make them the weapons of choice for insurgents, terrorists, and rogue nations looking mostly for tactical and/or psychological advantage.

This chapter provides an overview of recent incidents involving toxic weapon use, focusing on two especially prominent types of toxic warfare: poisonings and the use of chemicals and smoke. It ends with a discussion of notable developments in toxic warfare, including the use of toxic weapons within more sophisticated terrorist networks; a growing opportunism concerning the materials used to make toxic weapons; and an apparent increase in interest in using such weapons.

A caveat to the reader is in order, however. The goal of this chapter is to offer a relatively broad view of the range of possibilities associated with toxic weapons. This discussion is meant as a qualitative overview and does not purport to offer a quantitative analysis of the risks associated with particular kinds of toxic weapons or the consequences of specific attacks. It is hoped that the current discussion can help identify areas requiring further quantitative analysis.

## POISONING WITH CHEMICALS, SEWAGE, AND PESTICIDES

Many recent incidents of toxic warfare have involved poisoning with chemicals, sewage, or pesticides. All these substances can be used to interfere with military operations, disrupt the functioning of civilian infrastructure, cause physical harm, and instill fear among the general populace.[1]

Episodes of poisoning have a long history in toxic warfare. In 1986, the Liberation Tigers of Tamil Eelam (LTTE) poisoned tea with potassium cyanide in an effort to cripple the Sri Lankan tea export industry.[2] In December 1989, during civil unrest in Romania in conjunction with the collapse of the Ceaucescu government, the water supply for the city of Sibiu was poisoned with an organophosphate by Romanian nationalists.[3] In March 1992, water tanks at a

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[1]Water poisonings can occur, but only under the right conditions. Chlorine residuals and actual consumption of water nowadays limit toxic effectiveness and the utility of the fluoroacetates. According to Siegfried Franke, in terms of poisonings, some substances work well in waterworks, food supplies, and crops. The prerequisite for these applications is great resistance to hydrolysis or to the formation of equally poisonous products of hydrolysis. Sarin dissolves in water to an unlimited extent and hydrolyzes very slowly, and the same is true of the organic compounds of fluorine, which have been suggested for sabotage and diversion work. Other poisons or chemical warfare agents dissolve in water only to a limited extent, but their solubility and resistance to hydrolysis suffice to achieve effective contaminations. See Siegfried Franke, *Manual of Military Chemistry*, Vol. 1., Berlin: Deutscher Militärverlag, 1967, pp. 30 and 139. See also William H. Monday, *Thinking the Unthinkable: Attacking Fresh Water Supplies*, master's thesis, Naval Postgraduate School, Monterey, CA, AD-B241, December 1998.

[2]See Abraham D. Sofaer, George D. Wilson, and Sidney D. Dell, *The New Terror: Facing the Threat of Biological and Chemical Weapons*, Stanford, CA: Hoover Institution, 1999, p. 82.

[3]See "A History of Biological and Chemical Threats to Water Supply," *International Defense Review*, Vol. 32, No. 1, January 1, 1999, p. 58.

Turkish army base outside Istanbul were poisoned with potassium cyanide; suspicion was aroused when two empty 25-kg boxes were found next to the water tanks and a layer of foam was seen on the water. An investigation concluded that the Kurdish Workers Party (PKK) had launched the attack.[4] In 1994, during heavy fighting on the Thai-Cambodian border near Pailin, more than a dozen Khmer Royal Armed Forces combatants died after having consumed water from streams and ponds poisoned by opposing Khmer Rouge forces.[5] In 2000, Chechen rebels attempted to poison Russian soldiers with an unidentified toxic substance found in wine delivered to the soldiers by Chechen civilians.[6]

## The Israeli-Palestinian Conflict

The Israeli-Palestinian conflict has involved the use of pesticides, other chemicals, and sewage in toxic weapons. In October 1997, Israeli counterterrorism official Meir Dagan stated that he was afraid that toxic weapons were about to be used in the Israeli-Palestinian conflict.[7] During the same month, Israeli settlers from Gosh Etzion sprayed a chemical on Arab grape farms in the Ertas and Khader villages south of Bethlehem, ruining hundreds of grapevines and as many as 17,000 metric tons of grapes.[8] On June 19, 1999, Hamas announced plans to poison water supplies is Israel with "chemical sub-

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[4]The amount in question would not have caused death. See "Turks Report Attempt to Poison Air Force Unit," Reuters, March 28, 1992, as quoted in Monday, *Thinking the Unthinkable*, December 1998, p. 137.

[5]See "A History of Biological and Chemical Threats to Water Supply," January 1, 1999. Although the number of deaths caused by poisoning was much smaller than that caused by land mines in the region, the use of poison was nonetheless an effective terror weapon.

[6]See Jason Pate, Gary Ackerman, and Kimberly McCloud, *2000 WMD Terrorism Chronology: Incidents Involving Sub-National Actors and Chemical, Biological, Radiological, or Nuclear Materials*, Monterey, CA: Center for Nonproliferation Studies, available at http://cns.miis.edu/pubs/reports/cbrn2k.htm.

[7]See Yigal Sarna and Anat Tal-Shir, "Most of All He Likes to Disguise Himself and Operate in Enemy Territory," *Yediot Aharonot*, October 24, 1997, pp. 16–19, accessed from FBIS-FTS-19971102000227.

[8]See Shabatai Zvi, "Israeli Settlers Destroy 17,000 Tons of Grapes," *Al-Ayyam*, October 23, 1997, available at http://www.hebron.com/article04-10-23-97.html.

stances."[9] In November 1999, Israeli forces arrested an unidentified Hamas leader who had charts, tables, and specific instructions for mixing toxic substances into usable weapons. The materials were all obtained locally and were easy to disguise.[10]

In 2000, both Hezbollah and Hamas used insecticide in rockets or threatened to burn Israeli factories where industrial wastes were stored, creating clouds of toxic vapors.[11] In February 2000, Turkish authorities seized eight units of an unknown toxic substance during a weapons raid of Hezbollah facilities in Gazientep.[12] In June 2000, Palestinian news sources reported that Israeli settlers from the Efrat settlement on the West Bank had deliberately released sewer water into agricultural fields maintained by Palestinian settlers in the village of Khadder, near Bethlehem. According to local farmers, the release of the wastewater was part of an "annual tradition" designed to force Palestinian farmers off of their land.[13] In September 2001, Israelis used chemical fertilizer in a mass poisoning of 145 sheep and goats in the West Bank.[14]

Pesticides or other chemicals are also suspected to have been used as part of an attack by Palestinian suicide bombers in December 2001. Hazardous materials were found in a device detonated by the attackers, creating what officials believed was a crude attempt to make a

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[9]See Gavin Cameron, Jason Pate, Diana McCauley, and Lindsay DeFazio, *1999 WMD Terrorism Chronology: Incidents Involving Sub-National Actors and Chemical, Biological, Radiological, and Nuclear Materials*, Monterey, CA: Center for Nonproliferation Studies, Vol. 7, No. 2, Summer 2000, available at http://cns.miis.edu/pubs/npr/vol07/72/wmdchr72.htm.

[10]"Hot Mish'al," Channel 2 Television Network, November 8, 1999, accessed from FBIS-FTS-19991109000932.

[11]See Paul Bedard, "Danger Zone," *U.S. News & World Report*, March 6, 2000, p. 10.

[12]See Pate, et al., *2000 WMD Terrorism Chronology*.

[13]See "Settlers Pump Sewerage Water into Palestinian Groves," Palestine Information Network, June 21, 2000, available at http://www.palestine-info.net/daily_news/prev_editions/2000/June2000/21June.htm#9.

[14]See Tracy Wilkinson, "Microcosm of the Mideast Conflict in a Dead Flock," *Los Angeles Times*, September 1, 2001, p. A3; and Stefan H. Leader, "The Rise of Terrorism," *Security Management*, April 2001. The conclusion was reached after investigators found a large amount of cyanide along with manuals in the bombers' residences.

chemical weapon. One of the bombs used in the attacks on Jerusalem appears to have been immersed in some kind of chemical. An Israeli official noted that Palestinian bombers had apparently experimented with their explosive devices in order to "maximize the effect" by spreading hazardous materials in the vicinity of the blast.

## CHEMICALS, GASES, AND SMOKE

Chemicals, gases, and smoke can be used as part of traditional weaponry such as bombs and rockets or as weapons in themselves—as, for example, when industrial facilities are attacked to cause a chemical release. Several such uses are examined in this section.

### Bosnia

In the first week of August 1993, Bosnian Muslim forces used chlorine in 120mm shells on three occasions against Bosnian Serb forces. A few shells were fired at each decisive point of the battle either to facilitate a Muslim breakthrough or to stall the Serbs' advance. United Nations Protection Force (UNPROFOR) observers described the weapons as "crude, almost like home-made stuff with a radius of only 20 meters." The order to use chlorine for defense purposes came from Andjelko Makar, Chief of Staff of the Second Corps of the Bosnia-Herzegovina Army based in Tuzla.[15]

### Croatia

Serbian forces have frequently used toxic weapons, both as traditional weapons and through attacks on industrial facilities. As described in the introduction to this report, Serbian forces in Croatia used rockets, bombs, artillery, machine gun tracers, and mortars on six occasions between 1993 and 1995 to attack the Petrochemia plant, which produced fertilizer, carbon black, and light-fraction petroleum products. Hazardous substances at the plant included ammonia; sulfur (which poses a hydrogen sulfide inhalation hazard

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[15]See Yossef Bodansky, "Bosnian Muslim Forces' First Combat Use of Chemical Weapons," *Defense and Foreign Affairs Strategic Policy*, August 31, 1993, p. 16.

in the event of a fire); nitric, sulfuric, and phosphoric acids; heavy oil; and formaldehyde.[16]

Other chemical plants were attacked in the Croatian war. Serbian forces used rockets containing cluster bombs on a natural gas refinery in eastern Slavonia where ethane, propane, and butane were stored. Serbian forces also struck a chemical plant near the town of Jovan, releasing 72 tons of anhydrous ammonia and forcing the evacuation of 32,000 residents. Mortar attacks were launched on the Herbos pesticide plant located in Croatia's industrial center at Sisak. In addition, Serbian forces attacked large fuel storage tanks along the highway from Belgrade to the outskirts of Zagreb and started large fires at Osijek, Sisak, and Karlovak.[17] The refinery at Sisak, which produced liquefied petroleum gas (LPG), fuels, petroleum coke, and solvents, was hit particularly hard. Thousands of Serbian artillery rounds hit 38 storage tanks, destroying all of them. U.S. modeling efforts indicate that had the attacks destroyed existing stored chemical containers, lethal concentrations of chemicals would have covered a wide area.

Toxic warfare was also used against the Serbs. Muslim forces in Tuzla threatened chemical use in order to hold off a Serbian attack against the city, vowing to release large quantities of chlorine gas from railroad tank cars if the city was assaulted—despite the large number of friendly casualties that would have resulted from such an action.[18]

## Sri Lanka

During the 1990s, the LTTE used chemical waste to attack industrial facilities on several occasions as a means of creating confusion at strategic points. In November 1995, LTTE forces launched a gas attack on Sri Lankan troops in a bid to lift a siege on the rebel bastion of Jaffna, sparking heavy battles that left 84 dead on both sides. The

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[16]See FM 90-10-1, Q-8–Q-9. Refineries are usually designed so that two fires can be controlled and suppressed at one time, but at this refinery firefighters had to fight as many as five major fires simultaneously.

[17]Ibid.

[18]Ibid.

toxic attack was the first since 1990, when the LTTE fired chlorine gas cylinders into a besieged military camp near Batticaloa on the east coast.[19] In 2001, Tamil rebels attacked the Bandaranaike International Airport and military base with mortars. The first wave of attacks, launched at 3:30 a.m., targeted industrial and fuel facilities at the airport to create a fire and smoke diversion, while a second wave of mortars was aimed at both commercial and military aircraft. The resulting damage claimed 12 aircraft, costing millions of dollars, and closed the airport for a day.[20]

## Chechnya and Russia

In Chechnya, both Chechens and Russians have accused each other of ammonia and chlorine attacks. In 1995, a Chechen soldier described a Russian weapon that released an unknown toxic chemical:

> But one day an aircraft appeared and dropped a strange bomb. That is, it fell very strangely, rather slowly, flipping over and over the whole time. It detonated at a height of 120 meters above the ground and lots and lots of these little petals came out. They came whirling slowly down. At first we thought they were mines you know, the kind you scatter and if you step on them they blow off your foot. But then, after a while, they began to explode spontaneously. Not very loudly, but there were bangs throughout the forest. I went up and picked up one of these things. It went off in my hand. In the middle, between two petals, was a kind of capsule, about as big as a vial of brilliant green antiseptic. Some sort of liquid splashed out onto my clothing and a bit landed on my hand. I threw my jacket out, but later on there was a burning sensation on my hand, although I had immediately washed off the liquid with water. The smell was so bad it was impossible to breathe. It was disgusting. And there seemed to be a bit of a

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[19]See Agence France-Presse, November 25, 1995, accessed from FBIS-FTS-19951125000450.

[20]See "Tamil Rebels Raid Sri Lankan Airport," *Washington Post*, July 25, 2001, p. 14.

> smell of garlic. Then, a couple of days later, the leaves began to fall from the trees.[21]

This incident is particularly interesting because of the delivery system used, which was similar to a fuel-air explosive. However, the weapon was used to deliver not a mainstream chemical agent but some type of toxic substance or waste. Clearly, the Russians were modifying existing weaponry.[22] The incident also suggests something of the psychological uncertainty surrounding toxic warfare. The soldier recognizes that something toxic has landed on his clothing but doesn't know what it is. He also reports a feeling of revulsion at the substance's odor and has difficulty breathing as a result.

In both 1999 and 2000, Chechen rebels launched toxic attacks involving chemical and petroleum waste. On December 10, 1999, Chechens detonated previously prepared containers of chlorine and ammonia. As part of a battle with federal forces, they also ignited five oil wells, which burned up to 200 tons of oil per day.[23] The resulting smoke degraded the Russians' ability to observe the Chechens' actions and hence their ability to conduct military operations. In January 2000, Chechen forces tried to slow a federal force's offensive by blowing up 60-ton-capacity barrels in 111 rail cars loaded with chlorine solution and petroleum and emitting clouds of toxic gases.[24]

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[21]See Alexander Mnatsakanyan, "Were Chemical Weapons Used in Chechnya?" *Izvestia*, August 24, 1995, pp. 1–2, accessed from FBIS-FTS-19970502001427.

[22]Based on interviews with Eric Croddy from the Monterey Institute of International Studies and with analysts at the Armed Forces Medical Intelligence Center (AFMIC), July 2001.

[23]See "Grozny Gas Cloud Blown in Wrong Direction," Russian Public Television First Channel Network, December 29, 1999, accessed from FBIS-FTS-19991229001437; and "Five Oil Wells Still Ablaze in Chechnya," RIA, November 30, 1999, accessed from FBIS-FTS-19991201000318.

[24]See "Toxic Cloud in Chechnya: Rebels Detonate Chlorine Tank," RIA, December 10, 1999, accessed from FBIS-FTS-19991210000813; Pate et al., *2000 WMD Terrorism Chronology*; Mikhail Supotnitskii, "The Second Coming of Chlorine," *Nezavisimoye voyennoe obozrenie*, No. 1, January 2000, p. 4, accessed from FBIS-CEP-20000127000079; and Yevgenii V. Antonov, "Threat of Terrorist Attack Using Weapons of Mass Destruction from Chechnya," *Yadernyy kontrol*, No. 2, March–April 2001, pp. 55–70, accessed from FBIS-CEP-20010610000001.

Russia began to take the toxic threat seriously by sending NBC troops to the area and issuing gas masks and other protective measures for soldiers.[25] Military intelligence reported that mines, barrels, cisterns, and canisters filled with chlorine, ammonia, liquid nitrogen, and low-level radioactive waste stolen from medical and research waste disposal facilities[26] near Grozny had been placed at the intersections of major streets.[27] It is not entirely clear what Chechen rebels hoped to achieve through this particular combination of chemicals. In March 2000, Russian raids on Chechen positions in Grozny found ten tons of chlorine in preparation for deployment.[28]

Another example of the psychological impact of toxic weapons occurred in 2001, when rumors spread throughout Russia and the Persian Gulf of a Chechen plan to use chemicals. A Chechen chemist by the name of "Chitigov" (who was linked to the Chechen Arab warlord Khattab), together with "renowned chemist al-Khazur" from the United Arab Emirates, was reported to be trying to invent a chemical bomb in field conditions. The bomb was to be constructed from materials easily obtained from glass factories.[29] Rumors such

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[25]See Andrei Korbut, "Chechnya: The Ecological Threat Is Growing," *Nezavisimoye voyennoye obozrenie*, No. 176, January 28, 2000, available at http://nvo.ng.ru/wars/2000-01-28/2_ecohazard.html. See also Olga Oliker, *Russia's Chechen Wars 1994–2000: Lessons from Urban Combat*, MR-1289-A, Santa Monica: RAND, 2001.

[26]Medical waste as a potential toxic weapon also needs to be defined more clearly. In terms of biological sources, thousands of hospitals around the world produce millions of tons of infectious and medical waste every day. Clinics, colleges and universities, diagnostic laboratories, pharmaceutical companies, mortuary facilities, and doctors' offices also generate waste. Biological toxins can include human blood and blood products, cultures and stocks of infectious agents, pathological wastes, contaminated wastes from patient care, discarded biological materials, contaminated animal carcasses, body parts, bedding, and contaminated equipment. In addition, the disposal of infectious and medical waste is a problem because of its potential to transmit disease. Because commercial services for infectious and medical waste disposal are either poor or nonexistent in most areas of the world, these wastes may constitute a serious health hazard for military forces. The primary hazard is that these wastes remain infectious for years if left untreated.

[27]See Korbut, "Chechnya: The Ecological Threat Is Growing," January 28, 2000. See also Oliker, *Russia's Chechen Wars 1994–2000*, 2001.

[28]See "Snipers, Small Rebel Groups Remain in Grozny," ITAR-TASS, March 12, 2000, accessed from FBIS-CEP-20000312000074.

[29]See Timofey Borisov, "Smear a Grenade with Glue and Rain Down Hell," *Rossiyskaya gazeta*, August 30, 2001, as cited in "Paper Profiles Chechen Manufacturer

as this suggest the potential psychological impact of toxic weapons, which are made to seem more powerful than they really are. In the past, Chechens have used information operations to exaggerate their chemical and biological weapon (CBW) capabilities.

## TRENDS IN TOXIC WARFARE: ESCALATION OF USE, INCREASED SOPHISTICATION, EXOTIC COMBINATIONS

### Al-Qaeda and Osama bin Laden

The experience of Al-Qaeda and Osama bin Laden points to the dangerous combination of easy-to-obtain toxic weaponry and sophisticated terrorist networks. Toxic weapons seem to be used to an increasing extent in conjunction with more complex forms of organization, training, and equipment. Ever since the 1993 World Trade Center car bombings, when Al-Qaeda used cyanide in a bungled attempt to cause a toxic attack as well, Al-Qaeda has shown an interest in toxic warfare.[30] Al-Qaeda has experimented with cyanide gas in Derunta, Afghanistan.[31] Another bin Laden cell in Africa planned a cyanide attack in Europe.[32] After the September 11 terrorist attacks on the United States, U.S. Attorney General John Ashcroft told the Senate Judiciary Committee that several individuals linked to the hijackers had fraudulently obtained or attempted to obtain hazardous material transportation licenses.[33] While Al-Qaeda has a number of options available to it, toxic warfare may certainly be one of them.

of Toxic Weapons," accessed from FBIS-CEP-20010830000180. The same recipes are found in Osama bin Laden's training manual.

[30]See Craig Pyes and William C. Rempel, "Poison Gas Plot Alleged in Europe," *Los Angeles Times*, November 12, 2001, p. 10.

[31]See James Risen and Judith Miller, "Al Qaeda Sites Show Skills in Chemicals," *New York Times*, November 11, 2001, p. B1. See also Rory McCarthy, "Inside Bin Laden's Chemical Bunker," *The Guardian*, November 17, 2001; Keith B. Richburg, "Bin Laden and Bombs," *Washington Post*, November 22, 2001, p. A1; and Tom Walker, "Al-Qaeda's Secrets: Bin Laden's Camps Reveal Chemical Weapon Ambition," *Sunday Times* (UK), November 25, 2001.

[32]See Pyes and Rempel, "Poison Gas Plot Alleged in Europe," November 12, 2001, pp. 1 and 10.

[33]See "FBI Starts Nationwide Records Check on HAZMAT Truckers," CNN Online, September 26, 2001, available at http://www.cnn.com.

## The ELN and FARC

While the combination of toxic warfare with increasingly sophisticated terrorist networks represents one trend, increased opportunism in the use or combination of toxic substances represents another. In March 1998, for example, the ELN (the Army of National Liberation) mortar attacks outside Cucuta, Colombia, included two explosive charges at a checkpoint, killing Colombian soldier Alberto Moreno Vesga. According to a medical report, the ELN used "fecal material in the explosive devices, causing a high level of contamination in the wounds. Soldier Moreno died from wounds suffered on the arms, [and] legs, and a severe [sepsis] as a result of the fecal substances placed in the aforementioned explosives." A stream of toxic attacks has subsequently occurred. In late 2000, the ELN attacked the police department in Cajibio with sulfuric acid and ammonia. In March 2001, FARC (the Revolutionary Armed Forces of Colombia) attacked the police station in Puerto Lieras with pipe bombs that were loaded with glue, sulfuric acid, gasoline, tar, and feces.[34] In September 2001, FARC attacked the Huila police department with unidentified pulmonary agents thought to be chlorine.

## LTTE Sea and Land Attacks

The Tamil Sea Tigers (LTTE)[35] have used smoke and vapors both to create casualties and to cause deception, sometimes through elaborately staged or sophisticated means. In September 2001, the Tamil Sea Tigers attacked Bandaranaike Airport, destroying half of the Sri Lankan air fleet and causing millions of dollars of damage. Included was an attack on the airport's fuel depot that was aimed at spreading smoke and vapors.[36] The attack was intended to produce—and indeed resulted in—a spectacular mess that destroyed the fuel depot while also causing confusion and eventual military operations. One month later, in October 2001, a suicide squad from the LTTE sea

[34]See "FARC Allegedly Using Acid, Tar, Feces to Make Bombs," *El Tiempo*, September 6, 2001, accessed from FBIS-LAP-20010906000034.

[35]The Tamil Sea Tigers is the oceangoing version of the Tamil Tigers.

[36]See Rohan Gunaratna, "Intelligence Failures Exposed by Tamil Tigers Airport Attack," *Jane's Intelligence Review*, September 2001, pp. 14–17.

forces attacked the MV Silk Pride at sundown as the ship approached the Haffna peninsula. The oil tanker, carrying 225 tons of low-sulfur diesel, 160 tones of kerosene oil, and 275 tons of auto diesel, caught on fire.[37] LTTE fighters later participated in yet another toxic attack in an effort to interrupt Sri Lanka's economy.[38]

## RAISING THE LEVEL OF VIOLENCE?

This review of incidents involving toxic warfare suggests that interest in the use of such weapons may well be on the rise. Recent raids on Al-Qaeda cells both in Europe and in Afghanistan have uncovered manuals clearly illustrating that Al-Qaeda terrorists were thinking, among other things, about deploying toxic weapons. Those who use toxic weapons are also taking whatever opportunities become available to bend the definition of chemical warfare and conventional conflict through their choice of toxic materials and tactics. By breaking down the barriers concerning the types of materials that are used in attacks, terrorists and insurgents are looking to increase their opportunities to catch the adversary off guard and create uncertainty. These asymmetrical warfare options are by design far from those described by chemical warfare treaties and international warfare regulations. Terrorists are also incorporating toxic weapons into more complex preparation and planning strategies.

Taken together, these developments suggest that nonstate actors may be attempting to increase their military prowess through the use of toxic weapons. What this could mean for the United States and the U.S. Air Force will be the subject of the next two chapters.

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[37]See "Further on Tamil Tigers Attacking Oil Tanker in Sri Lanka," Agence France-Presse, October 30, 2001, accessed from FBIS-SAP-20011030000111.

[38]See "Guerrilla Suicide Boat Hits Sri Lankan Oil Tanker," Reuters, October 30, 2001.

Chapter Four

# TOXIC THREATS IN EXPEDITIONARY SETTINGS

U.S. forces have faced the specter of toxic attacks for some time. Typically, these attacks have been considered within the context of operations against countries such as North Korea and the former Soviet Union, and the primary weapons of concern have been militarized chemical and biological agents. However, the United States has given scant consideration to the use of more expedient toxic agents or to the damage that something short of chemical and biological warfare agents could cause.

Although U.S. operations have not yet faced repeated threats from toxic weapons,[1] that possibility clearly exists, particularly in light of the wide availability of toxic materials. Water supplies in areas of operations are vulnerable to intentional and accidental contamination. Toxic waste poses yet another threat, especially because an increasing number of U.S. operations are being conducted in urban industrial areas with decaying and wrecked chemical infrastructures.

U.S. forces frequently operate in environments in which there are toxic materials, particularly industrial chemicals. A number of these chemicals have the potential to interfere with U.S. operations in a significant manner across the range of military operations. Most toxic weapons can be released as vapors—which, as noted earlier, tend to remain concentrated downwind from the release point, in

[1]Previous studies of airfield intrusions and attacks show that quick attacks were the most successful. See David A. Shlapak and Alan Vick, *"Check Six Begins on the Ground": Responding to the Evolving Ground Threat to U.S. Air Force Bases*, MR-606-AF, Santa Monica: RAND, 1995; and Alan Vick, *Snakes in the Eagle's Nest: A History of Ground Attacks on Air Bases*, MR-553-AF, Santa Monica: RAND, 1995.

natural low-lying areas such as valleys, ravines, or man-made structures; or in any area with low air circulation. Explosions can create and spread liquid hazards, and vapors may condense to liquids in cold air.[2]

The U.S. military is currently seeking to improve its capabilities in responding to a range of possible terrorist threats, and toxic warfare is one such threat. Many U.S. military field manuals and related documents are in the process of being updated, and organizing, training, and equipping for toxic warfare are among the issues being addressed.[3]

This chapter focuses on risk and planning issues for U.S. forces engaged in expeditionary settings. We first examine the risks from toxic warfare for such operations. We then look at the current state of knowledge regarding such threats and identify gaps that need to be filled.

## U.S. OPERATIONS AND TOXIC WARFARE IN THE 1990S

Although the United States has had limited experience with toxic warfare, a review of past incidents involving toxic threats can point to some areas of potential vulnerability. One threat arises from toxic smoke in the field of operations.

The threat from toxic smoke is greatest for ground forces deployed to unstable areas, which today include Afghanistan, Pakistan, Uzbekistan, and Kyrgyzstan. Operation Desert Storm provides an example of the confusion and damage that can result from toxic

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[2]Four industry-standard dispersion models measure the spread of toxic materials: AFTOX, DEGADIS, INPUFF, and SLAB. See Breeze Software and Services, *Breeze Haz Materials*, available at http://www.breeze-software.com/content/haz/.

[3]The Chemical Corps Doctrine and Development Division of the U.S. Army Chemical School (USACMLS) conducted a study on lapses in doctrine regarding toxic warfare. They deemed that JP 1.02 (Joint Warfare of the Armed Forces of the United States), FM 101-5-1 (Operational Terms and Graphics), FM 3-100 (Chemical Operations Principles and Fundamentals), FM 3-3 (Chemical and Biological Contamination Avoidance), FM 3-11 (Flame, Riot Control Agents and Herbicide Operations), FM 3-18 (Special NBC Reconnaissance), and FM 34-54 (Battlefield Technical Intelligence) all need to be rewritten. See *USACMLS Doctrine Changes*, available at http://www.wood.army.mil/cmdoc/doctrine%20changes.pdf.

smoke, which can be used to impair vision and disrupt military operations. From January 25 to 27, 1991, Iraqi troops created a massive oil spill off Kuwait that ignited more than 700 Kuwaiti oil fields, sending smoke throughout the area of operations. In response, U.S. F-111Fs launched GBU-15 guided bombs that managed to destroy oil manifolds connecting storage tanks to the terminal. While this action drastically cut the flow of oil, oil fires continued to release large quantities of poisonous gases. In addition, some wells failed to ignite, forming vast pools of raw crude that covered hundreds of acres and created potential firetraps. So great was the smoke from burning oil wells that visibility was severely limited for coalition air forces in the Kuwaiti theater of operations (KTO). For fliers, the smoke created abrupt and repeated transitions from clear skies to instrument flying conditions. The weather also added to the problem, with black-spattering, oil-laden rain clogging engines in the air and on the ground.[4]

U.S. armed forces are also subject to contaminated supplies. Contamination can result from poor security on the part of outside suppliers as well as from the presence of toxic waste in and around the area of operations. One example of the risk of water contamination arose during Operation Just Cause. When U.S. forces landed in Somalia, the first priority for allied commanders was to supply fresh water to their forces on the ground. A plant located in Saudi Arabia had initially been commissioned to deliver thousands of pallets of bottled water at a cost of millions of dollars. Upon their delivery to Somalia, however, some of the bottles were found by U.S. Army chemists to be contaminated with fecal matter, and the entire lot was dumped. Until alternative sources of water could be found, most

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[4]See Federation of American Scientists, *Reaching Globally, Reaching Powerfully: The United States Air Force in the Gulf War—A Report—September 1991*, available at http://www.fas.org/man/dod-101/ops/docs/desstorm.htm; Federation of American Scientists, *Chapter VI—The Air Campaign*, available at http://www.fas.org/irp/imint/docs/cpgw6/cpgw_ch6_execute.htm; and U.S. General Accounting Office, *Operation Desert Storm: Evaluation of the Air Campaign*, Washington, D.C., GAO/NSIAD-97-134, June 1997, p. 5, Appendix IV:3. The Armed Forces Medical Intelligence Center stated that the detonation of the oil wells was intended to create flame barriers and to give off hydrogen sulfide gas contained in oil diverted from deep, high-pressure wells. If the petroleum is ignited in the presence of large quantities of natural gas, the effects would be similar to a fuel air explosive (FAE). See Federation of American Scientists, *AFMIC Weekly Wire 48-90*, available at http://www.fas.org/irp/gulf/cia/970129/970110_WW48090_90_0001.html.

U.N. contingents had to make do with Kenyan boxed water that was deemed clean. French forces had water flown in daily from Europe, which needed to be well guarded at French bunkers.[5]

## U.S. THINKING ABOUT TOXIC THREATS

Throughout the 1990s, the growing awareness of the threat posed by NBC weapons provided a foundation for learning more about the phenomenon. Toxic weapons using industrial chemicals are relatively easy to produce, as there is no need to synthesize, process, improvise agent delivery devices, or conduct testing. Little or no specialized knowledge of the manufacturing process is required. Toxic substances such as chlorine, phosgene, and hydrogen cyanide can easily be acquired and adapted.[6] For those seeking to use toxic weapons, the biggest threat is to avoid detection by authorities. Yet the wide availability of the substances used to make toxic weapons makes detection difficult.

An example of more formal U.S. thinking about potential toxic threats can be found in the 1997 *Assessment of the Impact of Chemical and Biological Weapons on Joint Operations in 2010*. This study examined, among other threats from chemical warfare, the potential for toxic weapons to disrupt U.S. military operations. The study identified local and asymmetrical attacks as the most likely threats to U.S. forces.[7] More specifically, the report examined a scenario in which a "blue team" uses chemical agents thinly to avoid lethal levels, which allows the force to impede U.S. military operations while complicating detection and cleanup. This report provides an idea of broad U.S. thinking about chemical weapons, al-

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[5]See Venter, "Poisoned Chalice Poses Problems," January 1, 1999.

[6]See U.S. General Accounting Office, *Statement of Henry L. Hinton, Jr., Assistant Comptroller General, National Security and International Affairs Division, Testimony Before the Subcommittee on National Security, Veterans Affairs, and International Relations, Committee on Government Reform, House of Representatives, Combating Terrorism: Observations on the Threat of Chemical and Biological Terrorism*, Washington, D.C, GAO/T-NSIAD-00-50, October 20, 1999.

[7]See U.S. General Accounting Office, *Report to Congressional Requesters, Chemical Weapons: DOD Does Not Have a Strategy to Address Low-Level Exposures*, Washington, D.C., GAO/NSIAD-98-228, September 1998.

though it does not offer a separate assessment of the response needed for toxic weapons.

In 1998, the Office of the Secretary of Defense (OSD) assessed the potential for a chemical attack to cause significant delays in the deployment of forces and to impair mission success. Although this OSD report did not specifically address toxic threats to the forces, it did examine the impact of a chemical or biological attack on an installation serving as a power projection site (i.e., one that our forces would use as a launching point in a time of crisis), using Fort Bragg and Pope Air Force Base (both located in Fayetteville, North Carolina) as its focus. The Pope/Bragg study concluded that chemical/biological attacks would significantly delay deploying forces and had the potential to impair the mission achievement of those forces. It further suggested that many of the vulnerabilities observed could be minimized through a preparedness program consisting of planning, training, exercises, and equipment. In consonance with this conclusion, the study recommended that DoD establish a program of installation preparedness to enhance awareness, plans, and preparations for the possibility of chemical or biological attacks at key force projection sites. This need formed the basis of the Pope/Bragg pilot.[8]

The U.S. Army Soldier and Biological Chemical Command (SBCCOM) has also developed a preparedness program for addressing issues relating to WMD. This program, which is directed toward U.S. military installations and has been successfully piloted at Fort Bragg and Pope Air Force Base, is based on the Army's experience in the Nunn-Lugar-Domenici Domestic Preparedness Program and on its participation in the Pope/Bragg study. The program's objective was to validate an approach toward preparing key military installations to respond to asymmetrical attacks involving WMD. Accordingly, it consisted of planning, training, exercises, and other technical assistance. The program targeted installation commanders and their staffs, installation emergency responders (fire, HAZMAT, and law enforcement/security personnel as well as health care

[8]See Paul Wolfowitz, Deputy Secretary of Defense, letter to the Honorable Bob Stump, Chairman, Committee on Armed Services, U.S. House of Representatives, Washington, D.C., April 25, 2001.

providers), and their counterparts in the local, state, federal, and host-nation communities.[9] The pilot programs succeeded in reducing delays in deployment by 45 percent on average and had a positive impact on the installation's other operations.[10]

Other work remains to be done to ensure that military doctrine adequately addresses the issue of toxic warfare. In conjunction with SBCCOM preparations, the Chemical Corps Doctrine and Development Division of the U.S. Army Chemical School found that several field manuals—JP 1.02, FM 101-5-1, FM 3-100, FM 3-3, FM 3-11, FM 3-18, and FM 34-54—need to be rewritten to reflect the potential for toxic warfare. The school argued that doctrine should be based on the description found in the *Assessment of the Impact of Chemical and Biological Weapons on Joint Operations in 2010.* Combined with the evidence that nonstate actors had been increasingly thinking about toxic warfare, FM 3-100 now pinpoints the need to identify toxic waste sites.[11]

## REMAINING ISSUES FOR EXPEDITIONARY OPERATIONS

The level of threat represented by toxic weapons remains to be determined. Should toxic warfare be considered a nuisance or a threat of strategic concern? Although it is impossible to know how extensively toxic weapons will be used in the future, the experience of toxic warfare to date and the kinds of urban operations in which the United States will likely be involved suggest that toxic warfare merits serious consideration as part of future planning strategies. There are several reasons for this conclusion:

- **The United States is not immediately aware of the location of toxic threats.** Overall, the U.S. military is actively aware of the potential for toxic threats, but the identification of specific threats is a painstaking process. In future operations, it is possible that an entire area of operations could be contaminated

[9] Ibid.

[10] Ibid.

[11] Ibid. Discussions with AFMIC analysts, 2000–2001.

with toxic waste.[12] Therefore, as the war on terrorism continues, U.S. forces will need to improve their knowledge of the locations of both legal and illegal sources of toxic waste as part of their intelligence assessments and contingencies.[13]

- **At the operational level, U.S. forces currently have no tailored response to toxic warfare in doctrine.** As the U.S. military develops a response to toxic warfare, it will need to provide a doctrinal response to resolve the trade-off between force protection and mobility/agility. One response to the potential for toxic warfare could be to bring chemical kits, protective clothing, cleanup materials, and the like, on every operation. Doing so, however, would impede the mobility and agility of the forces.

  Emergency response exercises and training should also be expanded to incorporate all the elements that could be involved in responding to a toxic attack. Air Force first responders currently exercise with their civilian counterparts on an annual basis, using the Disaster Response Force infrastructure to vary the types of NBC attack to include nuclear/radiological, biological, chemical, incendiary, and explosive materials.[14] The Air Force is investigating the possible use of the SBCCOM Program and services provided by the University of Texas A&M Emergency Responder Training Program. Three interactive training CD-ROMs for the emergency response to terrorism have been published by Headquarters, Air Force Civil Engineer Support Agency (HQ AFCESA) and distributed to all Air Force installations.[15]

- **The use of toxic weapons has implications for U.S. military lift and logistics.** As base security becomes more critical to operations, the vulnerability of key logistics sites has emerged as an

[12]Interview with a U.S Navy SEAL, 2001, who asked not to be identified. According to the interviewee, each operation is conducted in failed states filled with toxic waste, sewage, and radioactive waste.

[13]The author participated in the planning process by contributing to classified AFMIC products on toxic warfare and their presence in the Afghan theater.

[14]See Wolfowitz, letter to the Honorable Bob Stump, April 25, 2001.

[15]Ibid.

important issue.[16] Many sites are vulnerable to toxic attack, including ports, airfields, and related fixed sites that serve as choke points. Ports of embarkation (POEs) and en route facilities may be targeted in order to disrupt or inhibit U.S. military deployment both within and outside the threatened theater. For some large-scale operations, the en route structure is limited and may be a particularly lucrative target. Fixed sites are high-value targets for adversary toxic attack. Combat forces are vulnerable both during entry operations and during movement to areas of military operations. Support staging areas as well as rail and road networks are also potential targets, as are intermediate and infrastructure logistics bases. Aerial ports of debarkation (APODs) are vulnerable as well.

The APOD provides an example of how the U.S. Air Force can incorporate the possibility of toxic warfare into its planning. Because each APOD is unique, the size and operational flexibility of any particular site will affect the commander's options for preventing toxic contamination. To minimize the potential for aircraft to be exposed to toxic threats during ground operations, APOD plans need to include expedited offload procedures within the toxic threat area (e.g., engines running, no crew changes or refueling). It must also be recognized that in the event of contamination, some aircraft will not be able to land at or depart from certain areas of an aerial port regardless of its level of toxic preparedness. Instead, contaminated aircraft will need to be thoroughly decontaminated—a rigorous process if high-tech planes with advanced polymers are damaged or destroyed.[17]

- **At the tactical level, U.S. armed forces may not be ready for toxic warfare.** OSD has found a number of problems with preparation for toxic warfare as a subset of an NBC attack. Toxic waste vapors often hug the ground, an issue that is not addressed in some scenarios. On November 15 2001, the Air Force Deputy Chief of Staff/Installations and Logistics issued

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[16]See David A. Fulghum, "Terrorism Makes Base Protection Critical," *Aviation Week & Space Technology*, June 18, 2001, p. 196.

[17]See U.S. Air Force, *Civil Engineer Emergency Response Operations*, Air Force Manual 32-4004, December 1, 1995, pp. 70–80.

direction and guidance to all Major Commands on installation actions required for preparation of response to terrorist attacks with weapons of mass destruction. The document directed installations to plan, equip, train, and exercise installation emergency reponse capability for terrorist WMD events. Air Force publications to support this policy are in progress.

The Air Force is coordinating several documents to provide needed planning, organization, equipage, training, and exercise/evaluation program policy guidance for commanders and first responders. The planned policy guidance documents implemented Air Force Doctrine Document 2-1.8, *Counter Nuclear, Biological and Chemical Operation.* Other documents include Air Force Policy Directive 10-25, *Full Spectrum Threat Response*; Air Force Instruction 10-2501, *Full Spectrum Threat Response Planning and Operations*; Air Force Handbook 10-2502, *WMD Threat Planning and Response*; and Air Force Instruction 10-2601, *Counter NBC Operations.* The Air Force has developed its Baseline Equipment Data Assessment List in the event of a toxic or NBC attack.[18] Additional training is being developed.

- **Cleanup from a toxic attack may pose a difficult challenge.** Contaminated aircraft pose an especially difficult decontamination challenge, as demonstrated by the oil-laden rain that coalition forces confronted during the Gulf War. Fixed-site decontamination techniques typically focus on fixed facilities and mission support areas such as command, control, communications, computers, and intelligence ($C^4I$) facilities, supply depots, aerial and sea ports, medical facilities, and maintenance sites. However, cargo may require extensive decontamination measures, specialized and highly sensitive monitoring equipment, and extended weathering or destruction. It is therefore possible that equipment decontamination may have to be delayed until after conflict termination.[19]

In sum, the U.S. military is aware of the threat of toxic warfare, and some progress is being made to raise awareness through U.S. strat-

[18]Ibid.

[19]FM 90-10-1, Appendix A.

egy and doctrine. However, more work remains to be done in identifying and locating toxic threats, developing operational and tactical responses to toxic warfare, expanding training for responding to toxic attacks, and devising adequate cleanup procedures. The United States must also address the threat of toxic weapons within the homeland, as will be discussed in the next chapter.

Chapter Five

# TOXIC THREATS IN THE UNITED STATES

Toxic warfare is a threat not just for U.S. forces engaged in military operations but also for civilians within the United States. The risk is increased by the wide availability of toxic materials throughout the United States, together with the proximity of industrial operations to urban centers. In fact, the combination of large population centers and multiple toxic material sources poses a range of threats that need not involve warfare; accidents, incompetence, or employee malevolence could all produce a toxic incident with significant implications for civilian populations. Yet the potential for terrorists to use toxic weapons as part of a deliberate attack adds another dimension to this threat.

This chapter focuses on some of the issues relating to toxic threats in the United States and assesses the potential for an effective response in the event of a disaster. It also offers recommendations for civilian-military planning.

## AREAS OF VULNERABILITY

U.S. officials have been thinking about toxic warfare attacks on U.S. territory for some time. Prior to the 1996 Atlantic Olympics, for example, federal authorities considered potential threats from improvised chemical devices such as the use of high explosives by terrorists to puncture a train car loaded with chlorine gas. Since 1996, the

United States has routinely taken active measures to prepare for special events.[1]

Awareness has also increased with respect to the potential for toxic attacks involving hazardous materials. Since 1999, the Gilmore Commission has discussed the use of hazardous materials as toxic weapons. Commission members have investigated prevention, preparedness, mitigation, and response for HAZMAT scenarios and incidents in CONUS as well as chemical, biological, radioactive, and nuclear (CBRN), agroterror, and cyber threats.[2]

One issue of great concern remains the potential vulnerability of chemical and industrial facilities within the United States. Although available unclassified sources do not provide sufficient information from which to draw conclusions about the frequency of past attacks that have been planned or executed against industrial facilities, we can get an idea of the potential vulnerability of many such facilities from a recent example involving Greenpeace activists and a Dow Chemical plant near Baton Rouge, Louisiana. In February 2001, Greenpeace activists concerned about security problems in the chemical industry sought to underscore their point by scaling the fence of the plant, and they succeeded in gaining access to the control panel that regulates potentially dangerous discharges into the Mississippi River.[3] The activists' objective was not to release toxic materials into the river but rather to prove that Dow's security procedures were lacking. If terrorists had gained similar access, however, the results could have been devastating. At the plant, industrial chemicals such as chlorine, sulfuric acid, and hydrochloric acid could potentially provide terrorists with the materials necessary to create powerful toxic weapons. A 1999 study by the federal Agency for Toxic Substances and Disease Registry referred to these chemi-

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[1]See Jonathan Tucker, "National Health and Medical Services Response to Incidents of Chemical and Biological Terrorism" *JAMA*, Vol. 278, August 6, 1997, pp. 362–368, available at http://jama.ama-assn.org/issues/v278n5/ffull/jpp71006.html.

[2]See the materials under the Advisory Panel to Assess Domestic Response Capabilities for Terrorism Involving Weapons of Mass Destruction at http://www.rand.org/nsrd/terrpanel/.

[3]See Eric Pianin, "Toxic Chemicals' Security Worries Officials," *Washington Post*, November 12, 2001, p. A14.

cals as "effective and readily accessible materials to develop improvised explosives, incendiaries and poisons."[4]

The seriousness of the problem is directly related to the large number of sites in the United States containing chemicals capable of causing harm. Indeed, many of the chemicals used or produced in plants throughout the country have the potential to match or exceed the 1984 disaster in Bhopal, India. This risk is compounded by the frequent movement of these chemicals, typically by rail, through densely populated areas such as Baltimore and Washington.

The toxic threat within the United States is not limited to civilians. An attack could potentially affect or be directed toward one or more of the many military installations located here. Attacks on critical installations or embarkation points could delay, prevent, or degrade U.S. military operations for homeland protection or overseas deployment.

## STEPS FOR PROTECTING THE UNITED STATES FROM AND RESPONDING TO TOXIC WARFARE

How well are industrial facilities protected against the possibility of a toxic attack? In the aftermath of September 11, some U.S. industries have increased the precautions taken to protect their facilities. The chemical industry, for example, issued stringent new site security guidelines, and officials say they are in daily contact with the FBI and other federal authorities to prepare for a direct threat against a chemical plant.[5] Protective measures have also been temporarily increased to provide safeguards for industrial facilities and operations as well as to forestall the potential for retaliation during U.S. military operations. For example, immediately after the United States began bombing Afghanistan on October 7, 2001, the U.S. railroad industry imposed a 72-hour moratorium on carrying toxic or dangerous chemicals. These shipments were resumed, however, after the chemical industry argued that chlorine was essential to the continued operation of sewage treatment plants and that there was no evidence such shipments were being targeted by terrorists.

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[4]Ibid.

[5]Ibid.

The threat from toxic releases remains large. According to "worst-case" scenarios that companies are required by law to file with the Environmental Protection Agency, a single accident at any of the nearly 50 chemical plants operating between Baton Rouge and New Orleans could potentially put at risk 10,000 to one million people.[6] Environmental and hazardous chemical experts say that serious security problems also persist to varying degrees at chemical manufacturing centers in Texas, New Jersey, Delaware, Philadelphia, and Baltimore.[7] The Dow Chemical plant targeted by Greenpeace reported as its potential "worst case" the release of 800,000 pounds of hydrogen chloride, a suffocating gas that would threaten 370,000 people.

At the forefront of toxic warfare in the United States are the first responders—those individuals who are part of any "organization responsible for responding to an incident involving a weapon of mass destruction."[8] First responders include personnel from medical, law enforcement (or security), fire/rescue, HAZMAT, and explosive ordnance disposal (EOD) organizations. First responders receive extensive training and participate in frequent exercises. Yet while such training is likely to provide the basis for an effective initial response to a toxic attack, other crisis response capabilities need to be improved as well.

## ISSUES TO BE ADDRESSED

Despite the solid preparedness of first responders, other aspects of the U.S. crisis response network are lacking. Currently, for example, there is no consistent approach toward burden sharing among agencies, particularly with regard to treating casualties. Internet connectivity in many hospitals remains poor, with only 25 percent of laboratories up to federal standards for access and dissemination of information. Moreover, in the event of multiple toxic attacks, the scope of response needed could overwhelm local resources. Most U.S. hospitals are unprepared to deal with the casualties they would

[6]This scenario provides an estimate of the radius of a dangerous cloud of escaping gas and how many people could potentially be affected.

[7]See Pianin, "Toxic Chemicals' Security Worries Officials," November 12, 2001.

[8]Defense Authorization Act for FY 2001, in Section 1031.

see in the wake of a terrorist attack with toxic weapons, and hospitals have been slow to train staff and to equip facilities owing to a lack of funds.[9]

Military and civilian crisis response preparedness efforts must also be better coordinated. An opportunity exists for improved synergy between military preparedness and civilian expertise in areas such as HAZMAT. Civilian preparations for toxic threat have increased since September 11, and civilian organizations are improving their knowledge of the nature of the threat and the needed response. Additional organizing, training, and equipping are being provided at the state level. The U.S. military possesses chemical weapon prevention and cleanup expertise that is applicable to homeland security. Civilian organizations and first responders can benefit from working closely with the military in preparing to respond to toxic threats. The military can for its part expand its efforts to coordinate with civilian organizations in the event of a toxic attack. Such information-sharing and coordination efforts will be necessary to preparing an effective response to the threat of toxic weapons, particularly at a time when so many demands are being placed on the resources of civilian and military personnel involved in crisis response.

## FINAL THOUGHTS

Toxic warfare has been a reality for some time. Unfortunately, the continued use of small-scale toxic weapons as well as the persistent threat thereof signals that state and nonstate actors alike recognize that they are in possession of a potent new weapon. Foreign adversaries, including both state and insurgent/terrorist interests, increasingly see toxic warfare as a viable weapon for achieving their military and political goals.

U.S. understanding of this threat, while slow to mature, has improved, particularly for current counterterrorism operations. In

[9]See Daniel J. DeNoon, "Hospitals Not Ready for Terrorist Attacks," WebMD Medical News, January 26, 2000, available at http://www.webmd.com. Hospitals have three ranked priorities in the event of a HAZMAT incident. The primary duty is to protect current patients, staff, and the facility itself. The secondary duty is to give the best treatment possible to contaminated patients presenting for care. The final concern is to protect the environment outside the facility.

addition, the U.S. military is improving its ability to prevent and respond to toxic warfare. This report has provided a preliminary examination of an increased interest in asymmetrical toxic warfare among state and nonstate actors. U.S. forces—especially the U.S. Air Force—must continue to think about the problem and take appropriate steps for responding to it.

The risks associated with toxic warfare need to be better understood. Planning for military operations and civilian crisis response requires a detailed understanding of the benefits and costs associated with various options for countering toxic weapons. Military personnel and civilian officials are currently planning for a wide range of threats, all of which are competing for a limited pool of resources. While this research has aimed to show that toxic warfare merits greater attention, it has not attempted to quantify the risk by calculating the frequency of toxic attacks in relation to other kinds of risks or by assessing the full consequences of these weapons' use. A quantitative risk assessment should be considered as a means of providing a more thorough evaluation of the problem.

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**REPLY COMMENTS**
**OF**
**NORFOLK SOUTHERN RAILWAY COMPANY**

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# EXHIBIT 2

WWI The Medical Front

***Extracted from the 1917 book "Medical Diseases of the War" by Arthur Hurst, M.A., MD (Oxon), FRCP.***

***Chapter X describes the effects of chlorine gas poisoning, the patient's symptoms, prognosis and the treatment advocated in 1916. Of interest is the treatment of cyanosis by bleeding.***

***Dr M Geoffrey Miller, Editor***

# CHAPTER X
# GAS-POISONING

Poisonous gases are produced by all explosives, but owing to their rapid diffusion the majority are harmless unless they collect in closed spaces such as dug-outs or cellars. Under such conditions carbon-monoxide poisoning may occur (*vide* shell-shock). Shells which are specially constructed to set free asphyxiating and lachrymatory gases have been much used, but very little is known about their composition. The most serious form of gas-poisoning and the only one which will be considered in this chapter is that produced by heavy gases, which are set free in the enemy's trenches to drift with the wind. This brutal method of warfare was clearly premeditated, as shortly before the war a leading German pharmacologist and his pupils published papers which show that they were investigating the subject in great detail.

Asphyxiating gas was first used on April 22nd, 1915, in a German attack on Algerian and Zouave troops, who, being taken completely by surprise, broke before it. On the two following days attacks under cover of gas were made on Canadian and English soldiers in the neighbourhood of Ypres. Although no respirators were available and the losses were heavy, the troops held their ground. Another attack was made early in May; the men had now been provided with respirators, consisting of pads soaked in a solution of sodium bicarbonate, and these gave some protection. The third attack on May 24th and all subsequent ones have produced less serious results, as respirators of steadily increasing efficiency have been introduced.

The gas used has never been collected for analysis, but it is probably chlorine in most cases; indeed a deposit of chlorides has been found on the buttons of gassed soldiers. Chlorine was chosen on account of its exceptionally irritating character ; it rapidly puts a man out of action when inhaled in a strength of only 1 in 10,000, whereas sulphur dioxide is only effective in a concentration four times as great. Chlorine, being much heavier than air, readily drifts and sinks into trenches, dug-outs, and cellars. It can be rapidly manufactured in enormous quantities and is easily compressed into cylinders, in which it can be conveyed to the front.

The first effect produced by the irritant action of the gas is a profuse exudation of a thin, light yellow, albuminous fluid by the bronchial mucous membrane, as well as a very active secretion by the lachrymal and salivary glands; these are the results of protective reflexes, the object of which is to dilute the irritant poison and render it innocuous. At the same time spasm of the bronchial muscles occurs in an attempt to obstruct the passage of the gas into the alveoli. In severe cases the bronchial secretion and spasm not only fail to protect the alveoli, but obstruct the entry of air into the lungs, to such an extent that the patient becomes asphyxiated and may die before the fluid is expectorated and the spasm relaxes. An autopsy at this stage shows slight congestion of the larynx and intense congestion and oedema of the trachea and larger bronchi, which are filled with frothy fluid. The lungs are intensely congested and oedematous, but the violent respiration caused by the asphyxia produces small patches of over-distended lung, seen on the surface as light grey areas in the least damaged parts, into which air can still pass. The distended alveoli may rupture into the interstitial tissue, and air may spread into the mediastinum and even to the neck.

In all but the mildest cases the asphyxial stage is followed by a stage in which acute inflammation with profuse exudation of lymph occurs as a result of the irritant action of the gas on the bronchial mucous membrane and the alveoli. If the patient dies in this stage the serous fluid in the bronchi is replaced by muco-pus, and more or less extensive broncho-pneumonia is found.

There is no conclusive evidence that the chlorine is absorbed by the blood and conveyed by it to other parts of the body. Nephritis has occasionally been found post-mortem, though there has very rarely been any clinical evidence of its presence; thus albumin and casts are rarely found, oedema never occurs, and only one case of uraemia has been recorded. According to Leonard Hill, the nephritis is not due, as suggested by Bradford and Elliott, to the toxic action of the gas after absorption; he regards it as a result of asphyxiation and analogous to the condition which results from temporary occlusion of the renal artery. At a later stage secondary toxic effects may be_ caused by absorption of the products of the pathological changes in the lungs. If death occurs in the earlier stages, the right side of the heart is greatly dilated and the brain and all the abdominal organs show marked congestion due to asphyxia. The mucous membrane of the stomach is red and covered with thick yellowish mucus, submucous haemorrhages are common, and superficial erosions may be present: these changes are partly due to the asphyxia and partly to the irritant action of chlorine, dissolved in swallowed saliva and nasal and bronchial secretion.

## Symptoms.

The first effect of inhalation of chlorine is a burning pain in the throat and eyes, accompanied by a sensation of suffocation; pain, which may be severe, is felt in the chest, especially behind the sternum. Respiration becomes painful, rapid, and difficult ; coughing occurs, and the irritation of the eyes results in profuse lachrymation. Retching is common and may be followed by vomiting, which gives temporary relief. The lips and mouth are parched and the tongue is covered with a thick dry fur. Severe headache rapidly follows with a feeling of great weakness in the legs; if the patient gives way to this and lies down, he is likely to inhale still more chlorine, as the heavy gas is most concentrated near the ground. In severe poisoning unconsciousness follows; nothing more is known about the cases which prove fatal on the field within the first few hours of the "gassing," except that the face assumes a pale greenish yellow colour. When a man lives long enough to be admitted into a clearing station, he is conscious, but restless; his face is violet red, and his ears and finger nails blue ; his expression strained and anxious as he gasps for breath; he tries to get relief by sitting up with his head thrown back, or he lies in an exhausted condition, sometimes on his side with his head over the edge of the stretcher in order to help the escape of fluid from the lungs. His skin is cold and his temperature subnormal; the pulse is full and rarely over 100. Respiration is jerky, shallow and rapid, the rate being often over 40 and sometimes even 80 a minute ; all the auxiliary muscles come into play, the chest being over-distended at the height of inspiration and, as in asthma, only slightly less distended in extreme expiration. Frequent and painful coughing occurs and some frothy sputum is brought up. The lungs are less resonant than normal, but not actually dull, and fine riles with occasional rhonchi and harsh but not bronchial breathing are heard, especially over the back and sides.

Headache is generally severe, and there is also considerable epigastric discomfort, due partly to the strain of coughing and partly to gastric irritation, as it is increased if an attempt is made to eat.

The intense dyspncea of this asphyxial stage lasts about thirty-six hours, after which it gradually subsides, if death does not occur before. The patient, exhausted from his fight for breath, then falls asleep and wakes up feeling much relieved.

A few hours later acute bronchitis or broncho-pneumonia develops. In severe cases the quiescent interval is short and the bronchitis very severe. The sputum is now viscid, yellow or greenish, and muco-purulent with occasional streaks of blood. Respiration becomes more shallow and rapid, and the rate may finally be even 70 or 80 a minute. The pulse is small and very rapid ; the temperature rises, and is often as high as 104. The patient may now become delirious. Pleurisy may occur, and in some instances empyema and gangrene of the lung have followed.

After recovery from the bronchitis and pneumonia the patient remains weak and exhausted for a considerable time. He gets tired very rapidly and is unable to walk quickly or up hill without getting short of breath, even after the last signs of bronchitis have disappeared. He may continue to have attacks of dyspncea and cyanosis for several weeks. The frightful experience he has passed through often affects his nervous system, and some of the attacks are doubtless aggravated by apprehension. Headache, vertigo and dyspepsia may continue for several weeks.

**Prognosis**. Nothing is known as to the proportion of men who die from "gassing" on the field. Before efficient respirators were in use about 5 per cent. of those who reached the clearing stations died within forty-eight hours. Of those who reached the base hospitals between 1 and 2 per cent. died in the second or third week from broncho-pneumonia or other pulmonary complications.The mildest cases are often fit for light duty after a short period of rest, but they should not be sent back until all adventitious sounds have disappeared from the lungs. A considerable time elapses before complete restoration of health occurs in the more severe cases, and it is still doubtful whether more or less permanent incapacity may not sometimes follow.

**Prophylaxis**. The introduction of efficient respirators has almost abolished the danger of drift gas. Regular drill in the ***use*** of the respirators and inspection to see that they are in good condition are most important, as it takes time to get accustomed to breathing whilst wearing a respirator, and a damaged respirator may be worse than useless.

**Treatment**. The patient should be kept warm with extra blankets, hot-water bottles and hot drinks, and his bed should be near an open window or out of doors. Owing to the irritated condition of the stomach a fluid diet should be given at first. Absolute rest is of the greatest importance.

In severe cases the chief object of treatment is to expel the fluid, which is drowning the patient, from the lungs. This can be done by artificial respiration, repeated whenever the dyspncea becomes excessive. After squeezing the fluid out of the lungs, it may be necessary to blow air in from mouth to mouth in order to overcome the resistance of the froth in the smaller bronchi. An apparatus was introduced by Leonard Hill for use in collapsed and unconscious cases: a foot-pump feeds a face-mask through a flexible tube ; by each downstroke a measured volume of air or oxygen is pumped into the lungs, and by each upstroke a valve is opened which allows the air to escape by the elastic recoil of the thorax and lungs. From time to time the fluid is evacuated by squeezing the thorax and hanging the head over the side of the stretcher.

Unless the patient is collapsed or unconscious, vomiting gives great relief by expelling large quantities of yellowish frothy fluid from the lungs; if this does not occur spontaneously, the patient puts his finger down his throat after drinking half a pint of warm salt water. Ipecacuanha and apomorphine should not be used.

The inhalation of oxygen relieves cyanosis and improves the patient's condition. But it is very difficult to get a patient who is fighting for breath to tolerate any form of mask, without which it is impossible to give oxygen really efficiently. Administered in the ordinary way through an open funnel held near the patient's face the oxygen in the alveolar air is only increased by 1 or 2 per cent., whereas by using a mask and suitable apparatus the alveolar air should contain as much as 70 per cent. of oxygen.

Theoretically atropine should help to diminish bronchial spasm and secretion during the first twenty-four hours; but it has been found useless in severe cases and disappointing in slighter ones. Atropine is certainly valuable in the attacks of dyspnoea which may occur during convalescence, and I have found that stramonium taken regularly diminishes the liability to these attacks; potassium iodide in small doses is also useful.

Inhalations of ammonia are useful in the earliest stages, and after the second day ammonium carbonate in doses of gr. v every three hours produces copious expectoration, which results in improvement of colour and considerable relief. When great restlessness and mental distress are present, morphia should be injected.

Extreme cyanosis with a full pulse is greatly relieved by bleeding: breathing becomes easier, headache is relieved, and the patient falls into a refreshing sleep. Lian and Hebblethwaite found that the effect is most marked if venesection is performed in the first few hours. From 15 to 25 ozs. of blood should be slowly removed. The blood is dark and coagulates with abnormal rapidity. Bleeding is contra-indicated if the patient is pale and collapsed.

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Return to Medical Aspects Of Gas Warfare or to the WWI Medical Front index

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**REPLY COMMENTS**
**OF**
**NORFOLK SOUTHERN RAILWAY COMPANY**

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# EXHIBIT 3

<< Back to Occupational Safety and Health Guidelines

# Occupational Safety and Health Guideline for Chlorine

**DISCLAIMER:**

**These guidelines were developed under contract using generally accepted secondary sources. The protocol used by the contractor for surveying these data sources was developed by the National Institute for Occupational Safety and Health (NIOSH), the Occupational Safety and Health Administration (OSHA), and the Department of Energy (DOE). The information contained in these guidelines is intended for reference purposes only. None of the agencies have conducted a comprehensive check of the information and data contained in these sources. It provides a summary of information about chemicals that workers may be exposed to in their workplaces. The secondary sources used for supplements III and IV were published before 1992 and 1993, respectively, and for the remainder of the guidelines the secondary sources used were published before September 1996. This information may be superseded by new developments in the field of industrial hygiene. *Therefore readers are advised to determine whether new information is available.***

Introduction | Recognition | Evaluation | Controls | References

## Introduction

This guideline summarizes pertinent information about chlorine for workers and employers as well as for physicians, industrial hygienists, and other occupational safety ε *health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new* developments in these fields; readers are therefore advised to regard these recommendations as general guidelines and to determine whether new information is availat

## Recognition

**SUBSTANCE IDENTIFICATION**

* Formula
Cl(2)

* Structure
Not applicable.

* Synonyms
Bertholite, molecular chlorine

* Identifiers

1. CAS No.: 7782-50-5
2. RTECS No.: FO2100000
3. DOT UN: 1017 20
4. DOT label: Poison gas

* Appearance and odor

*Chlorine is a greenish-yellow gas with a characteristic pungent odor. It condenses to an amber liquid at approximately -34 degrees C (-29.2 degrees F) or at high pressu* Odor thresholds ranging from 0.08 to part per million (ppm) parts of air have been reported. Prolonged exposures may result in olfactory fatigue.

**CHEMICAL AND PHYSICAL PROPERTIES**

* Physical data

1. Molecular weight: 70.9
2. Boiling point (at 760 mm Hg): -34.6 degrees C (-30.28 degrees F)
3. Specific gravity (liquid): 1.41 at 20 degrees C (68 degrees F) and a pressure of 6.86 atm
4. Vapor density: 2.5
5. Melting point: -101 degrees C (-149.8 degrees F)
6. Vapor pressure at 20 degrees C (68 degrees F): 4,800 mm Hg
7. Solubility: Slightly soluble in water; soluble in alkalies, alcohols, and chlorides.
8. Evaporation rate: Data not available.

* Reactivity

1. Conditions contributing to instability: Cylinders of chlorine may burst when exposed to elevated temperatures. Chlorine in solution forms a corrosive material.
2. Incompatibilities: Flammable gases and vapors form explosive mixtures with chlorine. Contact between chlorine and many combustible substances (such as gasol and petroleum products, hydrocarbons, turpentine, alcohols, acetylene, hydrogen, ammonia, and sulfur), reducing agents, and finely divided metals may cause fi and explosions. Contact between chlorine and arsenic, bismuth, boron, calcium, activated carbon, carbon disulfide, glycerol, hydrazine, iodine, methane,

oxomonosilane, potassium, propylene, and silicon should be avoided. Chlorine reacts with hydrogen sulfide and water to form hydrochloric acid, and it reacts with carbon monoxide and sulfur dioxide to form phosgene and sulfuryl chloride. Chlorine is also incompatible with moisture, steam, and water.
3. Hazardous decomposition products: None reported.
4. Special precautions: Chlorine will attack some forms of plastics, rubber, and coatings.

* Flammability

Chlorine is a non-combustible gas. The National Fire Protection Association has assigned a flammability rating of 0 (no fire hazard) to chlorine; however, most combustib materials will burn in chlorine.

1. Flash point: Not applicable.
2. Autoignition temperature: Not applicable.
3. Flammable limits in air: Not applicable.
4. Extinguishant: For small fires use water only; do not use dry chemical or carbon dioxide. Contain and let large fires involving chlorine burn. If fire must be fought, use water spray or fog.

Fires involving chlorine should be fought upwind from the maximum distance possible. Keep unnecessary people away; isolate the hazard area and deny entry. For a massive fire in a cargo area, use unmanned hose holders or monitor nozzles; if this is impossible, withdraw from the area and let the fire burn. Emergency personnel sh stay out of low areas and ventilate closed spaces before entering. Containers of chlorine may explode in the heat of the fire and should be moved from the fire area if it possible to do so safely. If this is not possible, cool fire exposed containers from the sides with water until well after the fire is out. Stay away from the ends of containe Firefighters should wear a full set of protective clothing and self- contained breathing apparatus when fighting fires involving chlorine.

**EXPOSURE LIMITS**

* OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for chlorine is 1 ppm (3 milligrams per cubic meter (mg/m(3))) as a ceiling limit. A worker's exposure to chlorine shall at no time exceed this ceiling level [29 CFR 1910.1000, Table Z-1].

* NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) for chlorine of 0.5 ppm mg/m(3)) as a TWA for to a 10-hour workday and a 40-hour workweek and a short-term exposure limit (STEL) of 1 ppm (3 mg/m(3))[NIOSH 1992].

* ACGIH TLV

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned chlorine a threshold limit value (TLV) of 0.5 ppm (1.5 mg/m(3)) as a TWA for a normal 8-hour workday and a 40-hour workweek and a short-term exposure limit (STEL) of 1.0 ppm (2.9 mg/m(3)) for periods not to exceed 15 minutes. Exposures at t STEL concentration should not be repeated more than four times a day and should be separated by intervals of at least 60 minutes [ACGIH 1994, p. 15].

* Rationale for Limits

The NIOSH limits are based on the risk of severe eye, mucous membrane and skin irritation [NIOSH 1992].

The ACGIH limits are based on the risk of eye and mucous membrane irritation [ACGIH 1991, p. 254].

## Evaluation

**HEALTH HAZARD INFORMATION**

* Routes of Exposure

Exposure to chlorine can occur through inhalation, ingestion, and eye or skin contact [Genium 1992].

* Summary of toxicology

1. Effects on Animals: Chlorine is a severe irritant of the eyes, mucous membranes, skin, and lungs in experimental animals. The 1 hour LC(50) is 239 ppm in rats a 137 ppm in mice ()[Sax and Lewis 1989]. Animals surviving sublethal inhalation exposures for 15 to 193 days showed marked emphysema, which was associated with bronchiolitis and pneumonia [Clayton and Clayton 1982]. Chlorine injected into the anterior chamber of rabbits' eyes resulted in severe damage with inflammation, opacification of the cornea, atrophy of the iris, and injury to the lens [Grant 1986].
2. Effects on Humans: Severe acute effects of chlorine exposure in humans have been well documented since World War I when chlorine gas was used as a chemic warfare agent. Other severe exposures have resulted from the accidental rupture of chlorine tanks. These exposures have caused death, lung congestion, and pulmonary edema, pneumonia, pleurisy, and bronchitis [Hathaway et al. 1991]. The lowest lethal concentration reported is 430 ppm for 30 minutes[Clayton and Clayton 1982]. Exposure to 15 ppm causes throat irritation, exposures to 50 ppm are dangerous, and exposures to 1000 ppm can be fatal, even if exposure is bri [Sax and Lewis 1989; Clayton and Clayton 1982]. Earlier literature reported that exposure to a concentration of about 5 ppm caused respiratory complaints, corr of the teeth, inflammation of the mucous membranes of the nose and susceptibility to tuberculosis among chronically-exposed workers. However, many of these effects are not confirmed in recent studies and are of very dubious significance [ACGIH 1991]. A study of workers exposed to chlorine for an average of 10.9 yea was published in 1970. All but six workers had exposures below 1 ppm, 21 had TWAs above 0.52 ppm. No evidence of permanent lung damage was found, but 9 percent had abnormal EKGs compared to 8.2 percent in the control group. The incidence of fatigue was greater among those exposed above 0.5 ppm [ACGIH 19 In 1981, a study was published involving 29 subjects exposed to chlorine concentrations up to 2.0 ppm for 4- and 8-hour periods. Exposures of 1.0 ppm for 8 ho produced statistically significant changes in pulmonary function that were not observed at a 0.5 ppm exposure concentration. Six of 14 subjects exposed to 1.0 p for 8 hours showed increased mucous secretions from the nose and in the hypopharynx. Responses for sensations of itching or burning of the nose and eyes, an general discomfort were not severe, but were perceptible, especially at the 1.0 ppm exposure level [ACGIH 1991]. A 1983 study of pulmonary function at low concentrations of chlorine exposure also found transient decreases in pulmonary function at the 1.0 ppm exposure level, but not at the 0.5 ppm level [ACGIH 19 Acne (chloracne) is not unusual among persons exposed to low concentrations of chlorine for long periods of time. Tooth enamel damage may also occur [Parmeggiani 1983]. There has been one confirmed case of myasthenia gravis associated with chlorine exposure [NLM 1995].

* Signs and symptoms of exposure

1. Acute exposure: Acute exposure to low levels of chlorine results in eye, nose, and throat irritation, sneezing, excessive salivation, general excitement, and restlessness. Higher concentrations causes difficulty in breathing, violent coughing, nausea, vomiting, cyanosis, dizziness, headache, choking, laryngeal edema, a tracheobronchitis, chemical pneumonia. Contact with the liquid can result in frostbite burns of the skin and eyes [Genium 1992].
2. Chronic exposure: Chronic exposure to low levels of chlorine gas can result in a dermatitis known as chloracne, tooth enamel corrosion, coughing, severe chest p sore throat, hemoptysis and increased susceptibility to tuberculosis [Genium 1992].

**EMERGENCY MEDICAL PROCEDURES**

* Emergency medical procedures: [NIOSH to supply]

*Rescue: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the Material Safety Data Sheet required by OSHA's Hazard Communication Standard [29 CFR 1910.1200]).* All workers should be familiar with emergency procedures, the location and proper use of emergency equipment, and methods of protecting themselves during rescue operations.

**EXPOSURE SOURCES AND CONTROL METHODS**

The following operations may involve chlorine and lead to worker exposuresto this substance:

- The manufacture and transportation of chlorine
- Use as a chlorinating and oxidizing agent in organic and inorganic synthesis; in the manufacture of chlorinated solvents, automotive antifreeze and antiknock compounds, polymers (synthetic rubber and plastics), resins, elastomers, pesticides, refrigerants, and in the manufacture of rocket fuel
- Use as a fluxing, purification, and extraction agent in metallurgy
- Use as a bacteriostat, disinfectant, odor control, and demulsifier in treatment of drinking water, swimming pools, and in sewage
- Use in the paper and pulp, and textile industries for bleaching cellulose for artificial fibers; use in the manufacture of chlorinated lime; use in detinning and dezincing iron; use to shrink-proof wool
- Use in the manufacture of pharmaceuticals, cosmetics, lubricants, flameproofing, adhesives, in special batteries containing lithium or zinc, and in hydraulic fluids; use in the processing of meat, fish, vegetables, and fruit
- Use as bleaching and cleaning agents, and as a disinfectant in laundries, dishwashers, cleaning powders, cleaning dairy equipment, and bleaching cellulose

Methods that are effective in controlling worker exposures to chlorine,depending on the feasibility of implementation, are as follows:

- *Process enclosure*
- Local exhaust ventilation
- General dilution ventilation
- *Personal protective equipment*

Workers responding to a release or potential release of a hazardous substance must be protected as required by paragraph (q) of OSHA's Hazardous Waste Operations and Emergency Response Standard [29 CFR

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation--a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.
2. Burton DJ [1986]. Industrial ventilation--a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.
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5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

**MEDICAL SURVEILLANCE**

OSHA is currently developing requirements for medical surveillance. When these requirements are promulgated, readers should refer to them for additional information and to determine whether employers whose employees are exposed to chlorine are required to implement medical surveillance procedures.

* Medical Screening

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical surveillance program is intended to supplement, not replace, such measures. To detect and control work-related health effects, medical evaluations should be performed (1) before job placement, periodically during the term of employment, and (3) at the time of job transfer or termination.

* Preplacement medical evaluation

Before a worker is placed in a job with a potential for exposure to chlorine, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the skin, eyes, teeth, respiratory system, and cardiovascular system. Medical surveillance for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society.

A preplacement medical evaluation is recommended to assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to chlorine at or below the prescribed exposure limit. The health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditionswhich should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with diseases of the skin, eyes, teeth, respiratory system, or cardiovascular system.

* *Periodic medical evaluations*

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to chlorine exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of chlorine on the skin, eyes, teeth, respiratory system, or cardiovascular system. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

* Termination medical evaluations

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of placement should be repeated at the time of job transfer or termination to determine the worker's medical status at the end of his or her employment. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

* Biological monitoring

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for chlorine.

**WORKPLACE MONITORING AND MEASUREMENT**

Determination of a worker's exposure to airborne chlorine is made using amidget fritted glass bubbler (MFGB) containing a 0.1 percent solution of sulfamic acid. Sample: are collected at a maximum flow rate of 1.0 liter/minute until a maximum collection volume of 15 liters is collected for short-term (STEL or ceiling) samples, or 300 liters collected forTWA samples. Analysis is conducted using an ion specific electrode (ISE). This method is described in the OSHA Computerized Information System [OSHA ar fully validated. NIOSH Method No. 6011 (for chlorine or bromine) can also be used for the determination of a worker's exposure toairborne chlorine. This method require sample collection on a silvermembrane filter using flow rates of between 0.3 and 1.0 liter/minute until a minimum collection volume of 2 liters or a maximum collection volume of liters is reached. Analysis for this method is conducted using ionchromatography [NIOSH 1994].

## Controls

**PERSONAL HYGIENE PROCEDURES**

If chlorine contacts the skin, workers should flush the affected areasimmediately with plenty of water, followed by washing with soap and water.
Clothing contaminated with chlorine should be removed immediately, and provisions should be made for the safe removal of the chemical from the clothing. Persons laundering the clothes should be informed of the hazardous properties of chlorine, particularly its potential for causing severe irritation to the eyes, skin, and mucous membranes.

A worker who handles chlorine should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, using toilet facilities, appl cosmetics, or taking medication.

Workers should not eat, drink, use tobacco products, apply cosmetics, or take medication in areas where chlorine or a solution containing chlorine is handled, processed, stored.

**STORAGE**

Chlorine should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's Hazard Communication Standard [29 CFR 1910.1200]. Containers of chlorine should be protected from exposure to weather, extreme temperatures changes, and physical damage, and they should be stored separately from flammable gases and vapors, combustible substances (such as gasoline and petroleum products, hydrocarbons, turpentine, alcohols, acetylene, hydroge *ammonia,and sulfur), reducing agents, finely divided metals, arsenic, bismuth, boron, calcium, activated carbon, carbon disulfide, glycerol, hydrazine, iodine, methane,* oxomonosilane, potassium, propylene, silicon, hydrogen sulfide and water, carbon monoxide and sulfur dioxide, moisture, steam, and water. Workers handling and operating chlorine containers, cylinders, andtank wagons should receive special training in standard safety procedures for handling compressed corrosive gases. All pipe: and containment used for chlorine service should be regularly inspected and tested. Empty containers of chlorine should have secured protective covers on their valves a should be handled appropriately.

**SPILLS AND LEAKS**

In the event of a spill or leak involving chlorine, persons not wearing protective equipment and fully-encapsulating, vapor-protective clothing should be restricted from contaminated areas until cleanup has been completed. The following steps should be undertaken following a spill or leak.

1. Notify safety personnel.
2. Remove all sources of heat and ignition.
3. Keep all combustibles (wood, paper, oil, etc.) away from the leak.
4. Ventilate potentially explosive atmospheres.
5. Evacuate the spill area for at least 50 feet in all directions.
6. *Find and stop the leak if this can be done without risk; if not, move the leaking container to an isolated area until gas has dispersed. The cylinder may be allowed* empty through a reducing agent such as sodium bisulfide and sodium bicarbonate/li>
7. Use water spray to reduce vapors; do not put water directly on the leak or spill area.

**SPECIAL REQUIREMENTS**

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardou waste management may change over time. Usersare therefore advised to determine periodically whether new information is available.

* Emergency planning requirements

Employers owning or operating a facility at which there are 100 pounds or more of chlorine must comply with EPA's emergency planning requirements [40 CFR Part 355.30].

* Reportable quantity requirements for hazardous releases

A hazardous substance release is defined by EPA as any spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing into the environmentincluding the abandonment or discarding of contaminated containers) of hazardous substances. In the event of a release that is above the reportable quantity for that chemical, employers are required to notify the proper Federal, State, and local authorities [40 CFR
The reportable quantity of chlorine is 10 pounds. If an amount equal to or greater than this quantity is released within a 24-hour period in a manner that will expose persons outside the facility, employers are required to do the following:

- Notify the National Response Center immediately at (800) or at (202) 426-2675 in Washington, D.C. [40 CFR 302.6].
- Notify the emergency response commission of the State likely to be affected by the release [40 CFR 355.40].
- Notify the community emergency coordinator to the local emergency planning committee (or relevant local emergency response personnel) of any area likely to b affected by the release [40 CFR 355.40].

* Community right-to-know requirements

Employers who own or operate facilities in SIC codes 20 to 39 that employ 10 or more workers and that manufacture 25,000 pounds or more of chlorine per calendar ye or otherwise use 10,000 pounds or more of chlorine per calendar year are required by EPA [40 CFR Part 372.30] to submit a Toxic Chemical Release Inventory form (Fo R) to EPA reporting the amount of chlorine emitted or released from their facility annually.

* Hazardous waste management requirements

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA has specifically listed many chemical wastes as hazardous. Although chlorine is r specifically listed as a hazardous waste under RCRA, EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, a

State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (703) 412-9810 (in the Washington, D.C. area) or toll-free at (800) 424-9346 (outside Washington, D.C.). In addition, relevant State and local authorities should be contacted for information on any requirements they may have for the waste removal and disposal of this substance.

**RESPIRATORY PROTECTION**

* Conditions for respirator use

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of chlorine exce prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activi that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should only use respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

* Respiratory protection program

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's Respiratory Protection Standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular trainir of personnel, respirator fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the latest edition of the NIOSH Respirator Decision Logic [NIOSH 1987b] and the NIOSH Guide to Industrial Respiratory Protection [NIOSH 1987a].

**PERSONAL PROTECTIVE EQUIPMENT**

Workers should use appropriate personal protective clothing and equipmentthat must be carefully selected, used, and maintained to be effective in preventing skin conta with chlorine. The selection of the appropriate personal protective equipment (PPE) (e.g., gloves, sleeves, encapsulating suits) should be based on the extent of the worker's potential exposure to chlorine. The resistance of various materials to permeation by both chlorine liquid and chlorine gas is shown below:
Material Breakthrough time (hr) Chlorine liquid responder

Chlorine gas butyl rubber neoprene teflon viton saranex barricade chemrel responder trellchem HPS nitrile rubberH (PE/EVAL) polyethylene polyvinyl chloride
Material is estimated (but not tested) to provide at least four hours of protection. Not recommended, degradation may occur.
To evaluate the use of these PPE materials with chlorine, users should consult the best available performance data and manufacturers' recommendations. Significant differences have been demonstrated in the chemical resistance of generically similar PPE materials (e.g., butyl) produced by different manufacturers. In addition, the chemical resistance of a mixture may be significantly different from that of any of its neat components.

Any chemical-resistant clothing that is used should be periodically evaluated to determine its effectiveness in preventing dermal contact. Safety showers and eye wash stations should be located close to operations that involve chlorine.

Splash-proof chemical safety goggles or face shields (20 to 30 cm long, minimum) should be worn during any operation in which a solvent, caustic, or other toxic substa may be splashed into the eyes.

In addition to the possible need for wearing protective outer apparel e.g., aprons, encapsulating suits), workers should wear work uniforms, coveralls, or similar full-bod coverings that are laundered each day. Employers should provide lockers or other closed areas to store work andstreet clothing separately. Employers should collect wor clothing at theend of each work shift and provide for its laundering. Laundry personnelshould be informed about the potential hazards of handling contaminatedclothing instructed about measures to minimize their health risk.

Protective clothing should be kept free of oil and grease and should be inspected and maintained regularly to preserve its effectiveness.

Protective clothing may interfere with the body's heat dissipation, especially during hot weather or during work in hot or poorly ventilated work environments.

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**STB Finance Docket No. 35517**

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**CF INDUSTRIES, INC. v. INDIANA & OHIO RAILWAY COMPANY, POINT COMFORT RAILRWAY COMPANY, and MICHIGAN SHORE RAILROAD, INC.**

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**REPLY COMMENTS**
**OF**
**NORFOLK SOUTHERN RAILWAY COMPANY**

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# EXHIBIT 4

THE NEW ATLANTIS
A JOURNAL OF TECHNOLOGY & SOCIETY

# The Future of Chemical Weapons

Jonathan B. Tucker

In recent years, the nuclear ambitions of Iran and North Korea, and lingering fears of bioterrorism in the wake of the 2001 anthrax letter attacks, have overshadowed concerns that rogue states and terrorist organizations could acquire and use chemical weapons (CW). Whereas biological warfare agents are living microorganisms that cause deadly infectious diseases such as anthrax, smallpox, and plague, chemical warfare agents are manmade toxic chemicals such as chlorine, phosgene, and sarin nerve gas. Today the CW threat has all but disappeared from the radar screen of senior U.S. government policymakers, the news media, and the general public. In 2008, for example, the bipartisan Commission on the Prevention of Weapons of Mass Destruction Proliferation and Terrorism, chaired by former Senators Bob Graham (D.-Fla.) and Jim Talent (R.-Mo.), excluded any discussion of chemical weapons from its report, *World at Risk*. The rationale for this omission was that an incident of chemical terrorism would resemble a hazardous-materials accident and would be far less consequential than either a nuclear or biological attack. In November 2009, the Obama administration issued a new *National Strategy for Countering Biological Threats* but made no mention of chemical weapons.

The current sense of complacency about the CW threat is partly the result of several positive developments, including the demise of the Soviet Union, which possessed the world's most threatening chemical arsenal, and the entry into force in April 1997 of the Chemical Weapons Convention (CWC), an international treaty banning the development, production, transfer, and use of chemical arms, to which all but a handful of countries adhere. Nevertheless, there are real grounds for concern about a future resurgence of the CW threat. A confluence of military, economic, and technological trends—the changing nature of warfare in the twenty-first century, the globalization of the chemical industry, and the advent of destabilizing chemical technologies—have begun to erode the normative bulwark of the CWC and could result in the emergence of new chemical threats from both state and sub-state actors. To prevent these potential risks from materializing, much needs to be done at both the national and the international levels.

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## A Brief History of Chemical Warfare

Chemical weapons were first used on a large scale during World War I. In late 1914, the military imperative of breaking out of the bloody stalemate of trench warfare led the Prussian chemist Fritz Haber to propose releasing clouds of chlorine gas from pressurized cylinders in order to drive the enemy from his trenches. Once Germany broke the taboo against poison warfare at Ypres in April 1915, all of the other major combatants followed suit. By the end of the war, attacks with chlorine, phosgene, mustard gas, and other toxic agents had inflicted roughly one million casualties, about 90,000 of them fatal.

Despite the negotiation in 1925 of the Geneva Protocol banning the battlefield use of chemical weapons, their development continued during the inter-war period. In 1936, Gerhard Schrader, a German industrial chemist developing pesticides at the I. G. Farben company, accidentally discovered a new family of supertoxic poisons that attack the nervous system, causing convulsions and death by respiratory paralysis. The German Army subsequently developed these compounds into what became known as the G-series nerve agents, including tabun, sarin, and soman. Fortunately, Hitler never made use of these secret weapons during World War II, in part because German intelligence concluded—incorrectly—that the Allies had discovered them independently. In the early 1950s, industrial chemists at Imperial Chemical Industries in Britain developed a new pesticide called Amiton that soon proved too toxic for agricultural use and was pulled from the market. But Amiton was transferred to the British chemical warfare establishment at Porton Down and became the first of the V-series nerve agents, which readily penetrate the skin and are lethal in minute quantities: a drop of VX weighing 10 milligrams can kill a grown man in minutes. During the Cold War, the United States and the Soviet Union produced and stockpiled tens of thousands of tons of nerve agents in a shadowy chemical arms race that paralleled the more visible nuclear competition.

Chemical weapons also proliferated to several countries in the developing world and were used on the battlefield in the Yemen Civil War (1963-67) and the Iran-Iraq War (1980-88). During the latter conflict, Saddam Hussein first ordered the use of mustard gas in 1983 to counter Iran's numerical superiority and "human-wave" infantry tactics, which were overwhelming Iraqi positions. When his chemical attacks did not provoke international condemnation, Saddam became emboldened and initiated the use of nerve agents in March 1984 during the battle of

Majnoon Island. The Iranian forces were vulnerable to chemical attack because the Basij militia had no gas masks and the Revolutionary Guards refused to shave their beards, preventing their masks from achieving an airtight seal. Towards the end of the war, Saddam Hussein used chemical weapons as an instrument of terror against the restive Kurdish population in northern Iraq. In a notorious attack on March 16-17, 1988, the Iraqi Air Force dropped bombs containing mustard gas and nerve agents on the Kurdish town of Halabja, killing an estimated 5,000 civilians, many of them women and children. Terrorist groups such as Aum Shinrikyo in Japan and al-Qaeda in Afghanistan have also attempted to acquire and use chemical weapons, so far with limited success.

Some analysts have questioned whether chemical arms meet the criteria of a "weapon of mass destruction" because large quantities of an agent like sarin would be required to cause thousands of casualties in an outdoor attack. But if the threat posed by a weapon is thought of as the product of the likelihood of its use and the scale of the potential consequences, then chemical weapons must be taken seriously. Not only are the materials, equipment, and know-how for CW agent production more accessible to states and terrorist organizations than those for nuclear or biological weapons, but under the right atmospheric and weather conditions, toxic chemicals can have devastating effects on unprotected troops or civilians.

## CW Proliferation Today

Like a *chiaroscuro* painting by Rembrandt, the current status of CW proliferation is a mixture of light and shadow. On the bright side, the effective implementation of the Chemical Weapons Convention since its entry into force in 1997 has reduced the number of countries that possess chemical weapons from nearly twenty during the 1980s to a half-dozen today. To date 188 states, accounting for about 98 percent of the world's population and landmass, as well as 98 percent of the global chemical industry, have signed and ratified the CWC. This number is remarkable when one considers that the treaty has only been in force for a dozen years. Much of the credit for this achievement goes to the CWC's international secretariat, the Organization for the Prohibition of Chemical Weapons (OPCW) in The Hague, which has actively recruited new members.

The basic prohibitions of the CWC are comprehensive in that they ban the development, production, possession, transfer, and use of *all* toxic chemicals *except* for peaceful purposes and the preparation of defenses against chemical attack. This approach, known as the "general purpose criterion," ensures that the treaty cannot be overtaken by technological change: as soon as a novel CW agent is developed, it automatically falls under the purview of the CWC. For practical reasons, however, the treaty's stringent verification regime does not cover the entire universe of toxic chemicals, which is vast and continually expanding. Instead, verification is based on the finite set of chemical agents and precursors (key ingredients) that have been developed or used in the past for warfare purposes. These compounds are listed on three "schedules" in an annex to the treaty. Schedule 1 comprises known CW agents and their immediate precursors that have no utility for peaceful purposes, while Schedules 2 and 3 contain "dual-use" chemicals that can be diverted for CW agent production but also have legitimate industrial applications in small and large quantities, respectively. Together with quantitative production thresholds, the three Schedules serve as the basis for determining which chemical industry facilities in CWC member countries must be declared and opened up for routine visits by OPCW international inspection teams.

The CWC also requires the declaration of existing chemical weapons stockpiles and their destruction under strict international monitoring, as well as the dismantling or conversion to peaceful purposes of former CW production facilities. Seven parties to the treaty—Albania, India, Iraq, Libya, Russia, South Korea, and the United States—have declared chemical weapons stockpiles and proceeded to destroy them under international supervision. Three of the declared CW possessor states have already completed the destruction of their stockpiles: Albania in July 2007, South Korea in October 2008, and India in March 2009. Libya pledged to finish the job by December 31, 2010 but has encountered technical difficulties and was recently granted an extension until May 15, 2011, while Iraq has a small legacy stockpile of about 500 chemical munitions that it has yet to destroy. As of December 2009, about 56 percent of the world's declared total of 71,194 tonnes (metric tons) of CW agents had been verifiably eliminated.

The major problem facing the chemical disarmament process is that the United States and Russia, the world's two largest possessors of chemical weapons, are behind schedule in eliminating their vast toxic arsenals left over from the Cold War. As of December 2009, the United States had destroyed 66 percent of its stockpile while Russia had reached the 45 percent mark. At the current rate of destruction, the United States will have destroyed only 90 percent of its stockpile by the extended CWC deadline of April 29, 2012, and it is not expected to finish the job until 2021. Russia is also unlikely to meet the 2012 destruction deadline. Because the CWC has no provision for further extensions, the expected failure by the two largest CW possessors to eliminate their stockpiles on schedule could undermine the credibility of the chemical disarmament regime. Even so, Washington and Moscow remain committed to the goals of the CWC and have reaffirmed their intention to complete the task as soon as possible.

As membership in the CWC approaches universality, chemical weapons have lost any residual political legitimacy, even for purposes of retaliation or deterrence. Yet despite this new international norm, several countries continue secretly to possess chemical weapons and to upgrade their capabilities. At present, only eight states remain outside the CWC. Angola, Egypt, North Korea, Somalia, and Syria have neither signed nor acceded to the treaty; Israel and Burma (Myanmar) have signed but not ratified; and Taiwan would like to join but cannot because since 1971 it has not been a member of the United Nations. Four of the hold-out countries—Egypt, Israel, Syria, and North Korea—have been named in public sources as likely possessors of chemical weapons. In addition, the U.S. State Department's 2005 unclassified report on compliance with arms control agreements (the most recent available) publicly accused three CWC member states—China, Iran, and Russia—of violating their treaty obligations by retaining undeclared CW development or production facilities.

In order to address such allegations of noncompliance, the negotiators of the CWC built into the verification regime the option for any member state to request the OPCW inspectorate to conduct a short-notice challenge inspection of any suspect facility, declared or undeclared, that is located on the territory of another member state. This measure was intended as a "safety net" to capture clandestine chemical weapons development, production, or storage facilities that countries have deliberately not declared and hence are not subject to routine international inspection. Unfortunately, despite festering allegations of noncompliance, no state party to the CWC has yet requested a challenge inspection in the dozen years since the treaty entered into force. One reason for this inaction is that the CWC negotiators set a high bar for launching a challenge inspection by requiring the requesting state to provide evidence of a treaty violation. Not only is it politically risky for one member state to directly accuse another of cheating, possibly provoking a retaliatory challenge, but the failure of a challenge inspection to find "smoking-gun" evidence to substantiate the charge could end up letting the accused party off the hook, even if it is actually guilty.

The longer the CWC challenge inspection mechanism remains unused, however, the less it retains the power to deter violations. Accordingly, it would be desirable to lower the political threshold for launching a challenge inspection by using this measure to clarify ambiguities and concerns about compliance, such as whether or not a particular facility should have been declared, rather than attempting to catch a violator red-handed. Exercising the challenge-inspection option for clarification purposes would help to restore its credibility and also make it possible to work out the kinks in the process so that it does not have to be used for the first time in response to a crisis.

After most of the world's declared chemical weapons have been eliminated by the 2012 deadline, the primary focus of CWC implementation will shift from disarmament to nonproliferation, or efforts to ensure that chemical activities are conducted for non-prohibited purposes only. A key element of this task, as British CW analyst Julian Perry Robinson has pointed out, is "protecting against the malign exploitation of dual-use chemistry," meaning chemical materials, production equipment, and technologies that have both peaceful and military applications. Unfortunately, the CWC contains some major gaps with respect to verifying the non-production of chemical weapons at dual-use industry facilities.

First, because the three Schedules were compiled during the CWC negotiations in the 1980s and early 1990s and have not been updated since, they do not include a number of CW agents and precursors of more recent vintage. As a result, although the general purpose criterion bans the development or production of *any* chemical agent or precursor for hostile purposes, facilities that manufacture toxic chemicals not listed on the Schedules are exempt from routine inspection. The CWC does include an expedited procedure for updating the Schedules so that the verification system can keep pace with technological change, but member states have so far hesitated to use it. One reason for their reluctance is that adding new CW agents and their precursors to the Schedules would disclose sensitive information, such as the molecular structures of these compounds, that proliferators and terrorists could exploit.

Because facilities that produce unlisted CW agents and precursors are not subject to routine verification under the CWC, the only way to pursue suspected violations involving such chemicals is by requesting a challenge inspection, which has not occurred for the reasons noted above. Thus, to prevent would-be cheaters from circumventing the treaty and undermining its effectiveness, the member states must either find the political will to employ the challenge-inspection mechanism to pursue cases of alleged noncompliance or develop alternative ways of enforcing the general purpose criterion at the national and international levels.

## States of CW Proliferation Concern

Although unclassified information on states of CW proliferation concern is hard to come by, U.S. government reports and other public sources have identified a number of suspects. Even as Russia destroys the vast stockpile of chemical weapons it inherited from the Soviet Union, concerns linger about Moscow's compliance with the CWC. According to Russian military chemists who defected to the West, from the 1970s through the early 1990s the Soviet Union and then Russia ran a top-secret program called Foliant that successfully developed a new generation of nerve agents known as *novichoks*, after the Russian word for "newcomer." Reportedly, these compounds are more deadly and resistant to treatment than either the G-series or the V-series nerve agents. Dr. Vil Mirzayanov, a former Soviet military chemist who worked on the Foliant program, wrote in the Summer 2009 issue of the journal *CBRNe World*, "Agent 230 [a novichok], which was adopted as a chemical weapon by the Russian Army, is 5-8 times more poisonous than VX gas. It is impossible to cure people who are exposed to it."

Some of the novichoks consist of a "binary" formulation of two precursor chemicals, which would be stored in separate compartments inside a bomb or shell. After the munition was fired and en route to the target, the two precursors would be allowed to mix together and react to form the lethal agent, which would then be released on impact. (The United States, it should be noted, produced a binary sarin artillery shell from 1987 to 1990, before the CWC was concluded.) According to Mirzayanov, the novichok binary precursors were designed to lack the telltale molecular "signatures" of nerve agents, such as a carbon-phosphorus bond. Because of their relatively low toxicity, these chemicals could be manufactured in ordinary pesticide plants, making it hard for OPCW inspectors to detect them even during a CWC challenge inspection. The State Department cited these allegations in its 2001 arms control compliance report:

> since 1992, Russian scientists familiar with Moscow's chemical warfare development program have been publicizing information on a new generation of agents, sometimes referred to as "Novichoks." These scientists report that these compounds, some of which are binary agents, were designed to circumvent the Chemical Weapons Convention and to defeat Western detection and protection measures. Furthermore, it is believed that their production can be hidden within commercial chemical plants. There is concern that the technology to produce these compounds might be acquired by other countries.

Whether the Soviet Union or Russia ever produced and stockpiled the novichok agents in significant quantities is unknown, at least from open sources. Meanwhile, technical information about these deadly compounds has gradually leaked into the public domain through the publication of unclassified books and reports, raising concern that the knowledge to produce them could spread to rogue states and terrorist organizations. Because no effective antidotes against the novichoks are available, however, synthesizing and handling even small quantities of these agents would be exceedingly dangerous.

Outside Russia, chemical weapons proliferation today is concentrated in two regions of persistent conflict and crisis, East Asia and the Middle East. According to the State Department's 2005 arms control compliance report, "China continues to conduct CW research and development that has applications for either defensive or offensive purposes. China also has the capability to quickly mobilize its chemical industry to produce a wide variety of chemical agents." North Korea, for its part, has not signed the CWC and shows little interest in doing so. According to unclassified estimates by the South Korean government, Pyongyang has a chemical weapons stockpile of between 2,500 and 5,000 tonnes of mustard, phosgene, sarin, and V-series nerve agents. In addition, the North Korean army has deployed thousands of chemical-capable artillery pieces and multiple rocket launchers within range of Seoul, which would be devastated if war were to break out on the Korean Peninsula. Another Asian country that may possess an offensive CW capability is Burma (Myanmar). The human rights group Christian Solidarity Worldwide alleged in 2005 that the Burmese government was using chemical weapons against rebel fighters from the Karen ethnic minority, although these charges have not been corroborated.

In the Middle East, Syria reportedly has an advanced chemical arsenal, including large stockpiles of sarin and VX. It has also acquired hundreds of Scud-type ballistic missiles that could deliver chemical warheads against Israeli population centers. According to published assessments, this capability serves as a relatively inexpensive "poor man's atom bomb" that provides a partial counterweight to Israel's undeclared but widely acknowledged nuclear deterrent force. Beyond this strategic role, Syria might conceivably use chemical weapons to bolster its conventional military operations in the event of a war with Israel over the Golan Heights. Given the shortcomings of the Syrian army in past engagements with the Israel Defense Forces in 1967, 1973, and 1982, a CW capability might provide Syria with a greater range of tactical options.

Iran (unlike Syria) is a party to the CWC, but the U.S. government believes that it is secretly violating its treaty commitments. In early 2008, then-Director of National Intelligence J. Michael McConnell stated in congressional testimony that Tehran "maintains dual-use facilities intended to produce CW agent in times of need and conducts research that may have offensive applications. We assess Iran maintains a capability to weaponize CW agents in a variety of delivery systems." This testimony suggests that Iran may have eliminated its active CW stockpile (first acquired during the Iran-Iraq War) and switched to a "mobilization" strategy in which it would rapidly produce chemical weapons in the early stages of a crisis or war.

Egypt also appears to have a CW capability, although details are sketchy from public sources. The country employed chemical weapons in the 1960s during its military intervention in Yemen, and it later built an indigenous nerve-agent production capability at the Abu-Zaabal Company for Pest Control Materials and Chemicals near Cairo. Egypt also transferred chemical weapons and related technology to Syria in 1973 and Iraq in the 1980s. Although Egypt has so far refused to join the CWC in order to retain some political leverage vis-à-vis Israel's nuclear weapons capability, the Egyptian CW program appears inactive and may simply consist of a legacy stockpile.

Little public information is available about Israel's CW capabilities. Tel Aviv signed the CWC in January 1993, committing politically to abide by the basic aims of the treaty, but the Israeli parliament decided in 1997 not to ratify until all of Israel's Arab neighbors agree to follow suit. The top-secret Israel Institute for Biological Research near the town of Ness Ziona is known to conduct research and development on chemical defenses, but some suspect that it does offensive work as well. In addition, there have long been unsubstantiated rumors about an Israeli chemical weapons stockpile in the Negev Desert. Despite the potential harm to Israel's chemical industry from CWC-mandated restrictions on trade in Schedule 2 chemicals with countries that refuse to join the treaty, security rather than economic concerns have dominated the Israeli debate over ratification. Military analysts such as Gerald M. Steinberg of Bar-Ilan University have argued that the tacit threat of Israeli nuclear retaliation in response to a Syrian or Iranian chemical attack would not be credible because of its lack of proportionality, while relying exclusively on retaliation with conventional weapons would not provide a sufficient deterrent. According to Steinberg, by remaining outside the CWC, Israel creates uncertainty in the minds of potential military adversaries that it may have the capability to retaliate in kind to a chemical attack, thereby bolstering deterrence.

A major stumbling block to chemical disarmament in the Middle East has been the political and strategic linkage that exists between chemical and nuclear arms. Although neither Egypt nor Syria admit possessing chemical weapons, both countries have refused to join the CWC until Israel openly acknowledges its undeclared nuclear arsenal and accedes to the Nuclear Nonproliferation Treaty as a non-nuclear-weapons state. The current deadlock over chemical disarmament in the Middle East is likely to persist unless and until the peace process eases regional tensions and addresses the core security needs on both sides of the Arab-Israeli divide.

The regional picture is not entirely bleak, however. Over the past decade, several Arab countries have broken with the hard-line states by signing and ratifying the CWC. A particularly encouraging development was the rollback of Libya's CW program in 2004. Libyan leader Muammar Khaddafi, seeking to rejoin the international community after decades of diplomatic isolation and harsh economic sanctions, agreed to renounce his country's nuclear and chemical weapons programs, including a stockpile of more than 24 tonnes of mustard gas. After acceding to the CWC, Tripoli declared a former CW production plant that had been concealed inside a pharmaceutical factory at a site called Rabta, and proposed to convert the facility to the peaceful production of drugs and vaccines for the African market. Since Libya's accession to the CWC, Iraq and Lebanon have also joined the treaty, leaving Egypt and Syria as the last remaining holdouts in the Arab world.

This brief survey makes clear that despite significant progress toward global chemical disarmament since the entry into force of the CWC in 1997, the complete abolition of this category of armament remains a distant goal. Today about a half-dozen countries, both inside and outside the treaty regime, continue to possess chemical weapons. Even so, the nature of the problem has changed. "Vertical" proliferation, or the acquisition of larger stockpiles and more advanced agents and delivery systems by existing CW possessors, has essentially replaced the earlier process of "horizontal" proliferation, or the spread of chemical arms to additional states.

## The Changing Nature of Warfare

The nature of warfare in the twenty-first century is changing. Traditional set-piece battles between regular armies, as occurred during the 1991 Persian Gulf War and to a lesser extent in the 2003 Iraq War, are becoming increasingly rare. Instead, most military conflicts in the world today are civil wars, insurgencies, counterinsurgency campaigns, and low-intensity "operations other than war," such as U.N. peacekeeping and counterterrorism. This trend, combined with the ongoing implementation of the CWC and the political delegitimation of chemical warfare, make it unlikely that the large-scale battlefield use of chemical weapons will recur in the future. Nevertheless, much as "military necessity" (*Kriegsräson*) drove the resort to chemical weapons in World War I and the Iran-Iraq War, the new forms of conflict could create incentives to employ such arms. For example, insurgent groups may view poison gas as a means of asymmetric warfare against domestic or foreign armies that have vastly superior conventional military capabilities. Conversely, government forces might employ chemical weapons against rebel fighters and civilians in entrenched separatist enclaves, perhaps in a covert manner that makes such attacks difficult to confirm or attribute. Finally, because ethnic and communal wars feed on deep hatreds and are often fought in a savage manner with little regard for the laws of armed conflict, they could well outstrip the normative and legal restraints against the use of chemical arms.

Three examples of "improvised" chemical warfare in the recent past may be harbingers of the future. In June 1990, the Sri Lankan rebel group known as the Tamil Tigers fought a battle with the Sri Lankan Armed Forces (SLAF) near the town of Kiran on the island's east coast. Running low on conventional munitions, the Tigers seized cylinders of pressurized chlorine from a paper mill and released the gas upwind of a fort controlled by the SLAF. The toxic cloud injured more than sixty Sri Lankan government soldiers, enabling the rebels to overrun the fort. At the same time, some of the toxic gas drifted back into Tamil territory, angering the Tigers' constituency. In this case, the Tigers' use of a chemical weapon was opportunistic in that the chlorine was readily available and satisfied an urgent military need. As terrorism analyst John Parachini has noted, however, the rebels did not make further use of chemical weapons because they feared a loss of support from the local population and the Tamil diaspora, who were essential to the group's fundraising.

A second example of improvised chemical warfare occurred during the war in the former Yugoslavia between Serbia and Croatia (1991-1995). On six occasions from 1993 to 1995, Serbian forces used rockets, bombs, artillery, machine-gun tracers, and mortars to attack the Petrochemia chemical plant, one of Europe's largest fertilizer producers, which is located less than a kilometer from the Croatian town of Kutina. Because the Petrochemia facility stored a variety of toxic substances, including anhydrous ammonia, sulfuric acid, and formaldehyde, the Croatian Ministry of Defense deployed special hazardous-materials response units and a network of mobile and tower-based chemical sensors connected to a computer with a predictive dispersion model to prevent and mitigate hazards to the civilian population. Serbian forces also attacked a Croatian chemical plant thirty kilometers from the town of Jovan, resulting in the release of 72 tons of anhydrous ammonia. Fortunately, local public-safety officers had time to evacuate the town's 32,000 residents. In a third incident, the Serbians fired mortars at the Herbos pesticide plant in the industrial center of Sisak but did not hit critical process-control or chemical storage areas. Although none of the Serbian attacks on Croatian chemical facilities resulted in a major threat to public health, subsequent U.S. computer modeling determined that if existing chemical storage containers had been breached, lethal concentrations of toxic materials would probably have spread over a wide area. Future conflicts may well involve deliberate attacks on chemical plants with the intent of harming civilian populations, a tactic that Theodore Karasik of the RAND Corporation has called toxic warfare without weapons.

The most recent example of improvised chemical attacks took place in Iraq during the first half of 2007, when Sunni insurgents affiliated with the group Al-Qaeda in Iraq (AQI) decided to augment their vehicle-borne improvised explosive devices (IEDs) with chlorine, which is widely used in Iraq for water purification. On January 28, 2007, an AQI suicide bomber in the town of Ramadi detonated a truck laden with explosives and a tank of liquid chlorine. The blast killed sixteen people outright and also vaporized the chlorine, producing a cloud of noxious gas that caused vomiting and breathing problems in dozens of Iraqi civilians downwind and terrorized the community. Over the next six months, AQI operatives detonated several more truck bombs incorporating containers of liquid chlorine. Because the explosions burned much of the agent rather than dispersing it, the chlorine gas was not concentrated enough to cause many deaths. In an effort to enhance the toxic effects of the bombs, the insurgents experimented with different proportions of chlorine and explosive before finally abandoning the effort in June 2007. Although attacks with chemical IEDs have not recurred since, their repeated use in Iraq may have crossed a psychological threshold that could make a return to such tactics more likely.

## Changing Proliferation Dynamics

The chemical weapons threat is linked not only to changes in the international security environment but also to the process of economic globalization. Many developing countries have acquired the capability to manufacture their own fertilizers and pesticides, and multinational companies are building sophisticated multipurpose chemical plants in parts of the world where labor costs are low and environmental regulations are less stringent. At the same time, the burgeoning global trade in chemicals has reduced the effectiveness of traditional nonproliferation tools such as export controls. Forty-one industrialized countries (including the United States) participate in an informal forum called the Australia Group, in which they harmonize their national controls on exports of dual-use chemicals and equipment that can be used to produce CW agents. Yet companies from countries outside the Australia Group, such as China, India, and Russia, still sell controlled items to Iran and other states of proliferation concern. Corrupt middlemen have also been implicated in the illicit trafficking of CW precursors, including Frans van Anraat, a Dutch businessman; Q. C. Chen, a Chinese national; and Nahum Manbar, an Israeli citizen. Although governments are rarely complicit in illicit sales, they are often lax in enforcing national export controls.

Other CW proliferation trends are also worrisome. Several countries that possess chemical weapons programs have tried to become self-sufficient in the production of key precursor chemicals in order to reduce their dependence on foreign manufacturers and avoid cut-offs in supply. One strategy, known as "back integration," involves the domestic manufacture of CW precursors from simpler chemicals whose export is not restricted. Another means of circumventing export controls, called "secondary proliferation," entails the transfer of CW precursors, production equipment, and know-how from existing possessors to friendly states seeking chemical arms. According to a report in *Jane's Intelligence Review*, Iran helped Syria to plan, build, and manage five pilot plants for the production of CW precursors as part of a strategic cooperation agreement between the two countries. Finally, the globalization of the chemical industry has created a large pool of people with expertise in chemistry and chemical engineering who could potentially be recruited by states or non-state actors seeking to acquire a CW capability.

## Impact of Emerging Technologies

At the same time that the process of economic globalization is undermining traditional nonproliferation measures such as export controls, a number of emerging chemical technologies have the potential to transform the nature of the CW threat. The pharmaceutical industry, for example, uses a technique called "combinatorial chemistry" to discover promising drug candidates. This method involves the automated mixing and matching of molecular building blocks to generate a "library" containing thousands of structurally related compounds, which are then screened for a desired pharmacological activity such as the ability to inhibit a key enzyme. Although harmful substances discovered in this manner typically have no therapeutic value and are set aside, it would be fairly easy to "mine" a combinatorial database to identify highly toxic compounds that could be developed into CW agents. According to a group of experts convened by the International Union of Pure and Applied Chemistry (IUPAC) to discuss the implications of emerging technologies for the CWC, "Some new chemicals found by database mining will have toxicity characteristics that could lead to their being considered as chemical weapon agents." Before a new toxic chemical can be turned into an effective weapon, however, it must meet a number of additional requirements, including stability in long-term storage, an appropriate degree of volatility or persistence to ensure its effective dissemination, a low-cost production method, and the availability of medical antidotes to protect the attacker's own troops.

Recent advances in chemical production technology also have implications for the future of the CW threat. Chemical plants with flexible manufacturing equipment, such as versatile batch reactors and pipes that are easily reconfigured, are capable of switching rapidly from one product to another in response to shifts in market demand. Such multipurpose chemical plants are becoming more common in the developing world, increasing the risk that they could be diverted to the illicit production of CW agents or their precursors. In addition, chemical engineering firms in Germany, China, India, Japan, and South Korea are pioneering the use of "microreactors," continuous-flow reaction vessels the size of credit cards, in place of traditional large batch reactors for the production of fine chemicals, cosmetics, and pharmaceuticals. By operating hundreds or even thousands of miniaturized reactors, heat exchangers, and mixers in parallel, it is possible to produce tons of chemicals per hour. This emerging technology offers economic, safety, and environmental benefits, including improved control of reaction parameters, higher yields with fewer unwanted byproducts, reduced energy consumption and generation of hazardous wastes, lower capital and production costs, and the ability to scale up simply by adding more units ("numbering up"). Yet chemical microdevices have a potential dark side because they are particularly well suited for the synthesis of highly toxic and reactive compounds. Moreover, by in effect shrinking a chemical plant to the size of a bedroom and minimizing the amount of heat and the volume of liquid and gaseous effluents generated by the facility, miniaturized production equipment could eliminate the traditional intelligence "signatures" associated with illicit CW agent production.

Another trend in chemical manufacturing is the growing convergence between chemical and biological production methods. By employing a set of advanced genetic engineering techniques known as synthetic biology—explored in depth in these pages in Spring 2006 ("The Promise and Perils of Synthetic Biology")—it is now possible to endow bacterial or yeast cells with the specialized biochemical machinery needed to produce complex molecules of medicinal value that are difficult and costly to extract from natural sources. For example, Jay Keasling and his colleagues at the University of California, Berkeley, have inserted "cassettes" of genes coding for complex metabolic pathways into yeast cells, enabling them to produce the immediate precursor of the anti-malarial drug artemisinin, a complex molecule that is currently extracted from the sweet wormwood plant. At the same time, the pharmaceutical and biotech industries have learned how to synthesize potent natural substances called peptides (short protein fragments) in multi-ton quantities by strictly chemical means. Although both synthetic biology and peptide synthesis offer great benefits, they could potentially be misused to produce biological toxins and other naturally occurring compounds for CW purposes. At present, the production of peptides is not subject to routine verification under the CWC, a gap that will have to be addressed in the future. Also warranting clarification is the extent to which the treaty's definition of chemical production "by synthesis" covers biotechnological methods such as metabolic engineering.

## CWC Breakout Scenarios

One consequence of the spread of flexible chemical manufacturing technologies (including multipurpose plants, microdevices, and biotechnological processes) is that they could enable countries to acquire a "latent" or "virtual" capacity to produce CW agents without the need to build dedicated facilities for that purpose. Defense analyst Michael Moodie contends that a CWC member state intending to violate the treaty could carry out the research, development, and small-scale testing of a CW production line in secret and then maintain this capability in distributed form within its civilian chemical industry. In the event of a crisis or war, the country's leaders could decide to acquire an active stockpile of chemical weapons and convert one or more flexible manufacturing plants to clandestine CW agent production. The short lead-time required for start-up would limit the ability of potential adversaries to counter the threat by deploying improved chemical defenses.

This potential for rapid "breakout" from the CWC poses major challenges for the chemical disarmament regime. Not only is a standby CW production capability much harder to detect than an active stockpile or a dedicated manufacturing facility, but a dual-capable plant would violate the treaty only when it actually began to produce CW agents. Because obtaining hard evidence for a secret mobilization program would be difficult, effective concealment might be possible even in the face of fairly intrusive on-site inspections. For these reasons, a number of chemical weapons proliferators appear to be shifting to a rapid-breakout strategy. In recent years, for example, U.S. intelligence officials have asserted in congressional testimony that Iran does not have a CW stockpile but instead maintains dual-use production facilities that could manufacture chemical agents in wartime.

The problem of virtual proliferation warrants a recalibration of some of the verification measures in the CWC. In particular, there is a serious gap in coverage with respect to "other chemical production facilities" (OCPFs), a category of chemical industry plants that do not currently manufacture CW agents or precursors listed on the Schedules but are technically capable of doing so. The CWC requires that such facilities be declared if they produce more than 200 tonnes per year of "unscheduled discrete organic chemicals," yet member states are required to provide little information about such plants beyond the name and location of each site. As the chemical industry spreads around the world, economic powerhouses like China and India are building large numbers of OCPFs, of which an estimated 10 to 15 percent contain flexible manufacturing equipment that could be diverted fairly easily to CW agent production. Accordingly, the global proliferation of OCPFs poses a significant risk to the object and purpose of the CWC.

At present, only a small fraction of the roughly 4,500 declared OCPFs worldwide are selected each year for inspection by the OPCW. The site-selection algorithm is quasi-random but "weighted" to take account of the risk that a facility could be diverted to illicit production. In 2008, the OPCW international inspectorate visited 118 of the 4,478 OCPFs that were subject to inspection that year, or 2.6 percent—a fraction far from sufficient to provide confidence in CWC compliance. To help bridge this gap in the verification regime, the member states should authorize the OPCW to conduct a significantly larger number of OCPF inspections per year. The organization should also be directed to refine the site-selection algorithm so as to target inspections on the multipurpose chemical plants that pose the greatest risk of diversion for prohibited purposes. Finally, to avoid wasting scarce inspection resources on facilities that pose no risk to the CWC, the member states should voluntarily declare more detailed information about their OCPFs than the treaty requires.

## Chemical Incapacitating Agents

Another issue of concern with respect to the future of the chemical disarmament regime is the fact that Russia, the United States, the Czech Republic, and possibly China are developing chemical incapacitating agents for use in counterterrorism operations, as well as hostage-rescue situations in which terrorists and innocent civilians are intermingled. Although chemical incapacitants are often termed "non-lethal agents," that term is a misnomer because such chemicals may cause death or permanent injury at high doses.

Russia has already made use of a powerful incapacitating agent, with disturbing results. On October 23, 2002, a band of Chechen separatists took about eight hundred people hostage during a performance of the popular musical *Nord-Ost* at the Dubrovka Theater in Moscow and threatened to set off explosives unless their demands were met. Russian special forces surrounded the theater, and a standoff with the rebels ensued that lasted for the next fifty-seven hours. Finally, at 5:15 a.m. on October 26, the Russian commandos pumped a vaporized narcotic drug (reportedly, a mixture of derivatives of the synthetic opiate fentanyl) into the theater's air-conditioning system and stormed the building about forty-five minutes later. The drug knocked out the female Chechens guarding the hostages, allowing the commandos to shoot them at point-blank range; the male Chechens had moved into the lobby and did not succumb to the gas as quickly, but they were killed in the ensuing firefight. Although all forty-one militants died, exposure to the powerful narcotic also claimed the lives of 129 of the hostages, demonstrating that its "non-lethal" character was a myth. In fact, no known chemical agent can incapacitate people quickly and without risk of death when employed under realistic field conditions in a military or law enforcement operation. Furthermore, the refusal of the Russian special forces to disclose the identity of the incapacitating agent prevented emergency medical personnel from administering antidotes in a timely manner. Even today, the exact composition of the narcotic gas remains a mystery. Despite the heavy loss of innocent life, the Russian government declared the hostage-rescue operation a success and is likely to employ chemical incapacitants again in future incidents of this type.

Surprisingly, the use of a potent chemical agent in the Dubrovka Theater incident was not considered a violation of the CWC, to which Russia is a party. Although the treaty bans the military use of toxic chemicals, including harassing agents such as tear gas, paragraph 9(d) of Article II allows member states to possess and employ toxic chemicals for "law enforcement including domestic riot control," as long as the types and quantities of such chemicals are consistent with law enforcement purposes. The negotiators of the CWC included this exemption to permit capital punishment by lethal injection (at the request of the United States), as well as domestic riot control using CS tear gas and similar agents that have temporary irritant effects on the eyes and skin. Because the law enforcement exemption in Article II.9 (d) is so vague, however, it does not explicitly rule out the use of more potent chemicals such as fentanyl, which unlike tear gas has depressant effects on the central nervous system that persist for several hours after exposure. For this reason, fentanyl-like chemicals are not considered riot-control agents but are more properly termed incapacitants, a category that is not defined in the CWC. It is also unclear whether or not the law enforcement exemption extends beyond domestic police use of toxic chemicals to cover counterterrorism operations conducted by paramilitary forces or U.N.-authorized peacekeeping missions overseas.

Given these ambiguities in the CWC, arms control advocates worry that some member states will interpret the law enforcement exemption too broadly, creating a major loophole that allows the development, production, and use of a new generation of potent incapacitating agents and specialized delivery systems, such as airburst munitions and mortars. If the acquisition of chemical weapons under the law enforcement exemption of the CWC continues unchecked, it could seriously undermine the treaty. In 2008, an IUPAC technical expert group warned,

> Activities to develop "non-lethal" weapons based on incapacitating agents would not easily be distinguishable from aspects of an offensive CW program: The agents would actually be weaponized, and the considerations with regard to the time between the discovery of a new toxic chemical that might be a candidate novel CW agent and its emergence as a CW may no longer apply.

Of particular concern is the possible development of a new generation of biochemical "calmative" agents that would act on the central nervous system in highly specific ways. Pharmaceutical companies are currently developing new therapeutic drugs modeled on natural body chemicals called "bioregulators," many of them peptides, that control vital homeostatic systems such as temperature, sleep, water balance, and blood pressure. In the brain, a large class of bioregulators act on neural circuits to modulate awareness, cognition, and mood. Based on this research, it may eventually become possible to develop modified bioregulator molecules called analogues that can cross the blood-brain barrier and induce a state of sleep, confusion, or placidity, with potential applications in law enforcement, counterterrorism, and urban warfare. Such chemicals are often referred to as "mid-spectrum agents" because they exist in a gray area between chemical and biological weapons. As Neil Davison of the British Royal Society has observed, even if future technical advances permit the development of safer incapacitants that are rarely lethal under operational conditions, the broader issue is "whether the police and militaries of the future (not to mention the criminals, terrorists, torturers, and dictators) should have access to chemical weapons to manipulate human cognition, perception, emotion, motivation, performance, and consciousness." Such agents could easily be misused for the repression of legitimate dissent, coercive interrogation, and other violations of human rights.

Ironically, even as the successful implementation of the CWC has helped to solidify a global norm against the use of chemical weapons, an entire category of toxic chemicals appears to be regaining legitimacy. To minimize the potential threat that an overly broad interpretation of the law enforcement exemption poses to the integrity of the chemical disarmament regime, there is an urgent need for greater transparency. As a first step, CWC member states should agree to declare the types and quantities of incapacitating agents they have produced and stockpiled, as the treaty already requires for riot-control agents. Restrictions on the types and quantities of incapacitating agents that may be employed for law enforcement purposes (including counterterrorism operations) should also be considered, along with rules of engagement for their use. As Julian Perry Robinson has argued, "If one form of toxicity suddenly becomes acceptable, the norm against weaponizing toxicity in all its forms, which is the norm that underpins the CWC regime, will be weakened and the floodgates perhaps opened."

## Chemical Terrorism

Although the number of states that possess chemical arms has declined significantly since the entry into force of the CWC in 1997, interest in such weapons on the part of terrorist organizations has not. Chemical terrorism can be divided into three types of scenarios: (1) synthesis and delivery of military-grade agents, such as mustard and sarin; (2) deliberate release of toxic industrial gases, such as chlorine or phosgene; and (3) sabotage of a chemical plant, industrial complex, or chemical-transportation system, releasing toxic materials that harm the local population.

Fortunately, the combination of motivation and technical capability needed to carry out a successful chemical attack is rare. With respect to motivation, terrorist groups that have political objectives, such as the Irish Republican Army, generally have a strong incentive to calibrate their use of violence to avoid alienating their supporters and funders. Politically motivated groups also tend to be conservative in their choice of weapons and tactics, innovating only when forced to do so by the introduction of new countermeasures. In contrast, terrorist groups that would use chemical weapons must be willing to inflict indiscriminate casualties and to pursue risky, innovative tactics. Types of groups that fit this profile include those with a millennialist, racist, or religious ideology, such as apocalyptic cults, radical militias, and jihadist organizations. Toxic chemicals may be attractive terrorist weapons because they inspire extreme dread, enabling even small-scale attacks to have a disproportionate psychological impact. This effect is further amplified by obsessive media coverage, particularly on cable television news, deeply frightening the public and challenging the authority of political leaders.

In addition to motivation, acquiring a CW capability requires overcoming a set of challenging technical and logistical hurdles. Chemical terrorists seeking to use military-grade agents, such as sarin or VX, must acquire the equipment and know-how needed to synthesize, handle, and deliver highly toxic materials. Because of these technical difficulties, all incidents of chemical terrorism to date have been fairly crude and limited in scale and scope. The most notorious attacks were carried out by Aum Shinrikyo, a bizarre doomsday cult in Japan. In the mid-1990s, Aum sought to manufacture 70 tonnes of sarin nerve agent for attacks against the Japanese parliament and government ministries in downtown Tokyo. The cult's aims were to fulfill the apocalyptic prophecies of its leader Shoko Asahara and trigger a massive social upheaval that would topple the Japanese government, opening the way to the establishment of a theocratic state under Asahara's command. These wildly ambitious goals would have remained in the realm of fantasy except for the fact that Aum had accumulated vast wealth—estimated in the hundreds of millions of dollars—from an array of legitimate and criminal enterprises, including computer stores, vegetarian restaurants, and drug trafficking, as well as appropriating the property of affluent individuals who joined the cult.

Flush with cash, senior Aum leaders recruited synthetic organic chemists from Japanese universities and used front companies to purchase a $10 million chemical pilot plant from Switzerland and large quantities of nerve-agent precursors from foreign suppliers. Aum even procured a military helicopter from corrupt officials in Russia with the aim of spraying sarin over the intended targets, but the cult was unable to keep the aircraft in working order. Aum operatives did carry out two small-scale attacks with sarin, the first in the town of Matsumoto in June 1994 and the second on the Tokyo subway in March 1995. In both cases, the poor quality of the nerve agent and the crude means of delivery limited the number of fatalities to seven and twelve, respectively—fewer than would have resulted from a conventional high-explosive bomb—although hundreds more were injured and the attacks had a pervasive terrorizing effect.

Analysts have drawn different lessons from the Aum Shinrikyo case. Those experts who tend to play down the threat of unconventional terrorism argue that, despite Aum's strong motivation to acquire chemical weapons and its access to technical know-how and financial resources, the cult failed in its efforts to scale up the manufacture of sarin and to deliver it in a way that would cause thousands of deaths. The skeptics conclude from this evidence that even fairly sophisticated terrorist groups are incapable of carrying out mass-casualty chemical attacks. More pessimistic analysts point out that Aum had only forty-eight hours to produce the sarin used in the subway incident because the cult leaders had been tipped off to an impending police raid on their headquarters, which they sought to block with a diversionary chemical attack in downtown Tokyo. Because the nerve agent was synthesized in haste in a small laboratory, it was less than 30 percent pure, and Aum scientists also lacked the time to devise an effective delivery system, such as an aerosol sprayer. Instead, they filled dual-ply plastic bags with the dilute sarin solution, which cult operatives carried onto subway cars and punctured with sharpened umbrella tips, producing puddles of sarin that slowly evaporated. If Aum had taken more time to prepare the chemical attack, it might have been far more devastating.

Another terrorist organization that has actively pursued chemical weapons is al-Qaeda, which launched a CW development program in the late 1990s in eastern Afghanistan under the direction of a chemist named Midhat Mursi al-Sayyid Umar, better known as Abu Khabab al-Masri. A former scientist in the Egyptian chemical weapons program, al-Masri had joined Egyptian Islamic Jihad, which merged with al-Qaeda in 1998. He subsequently took charge of al-Qaeda's chemical weapons program, known as Project al-Zabadi. Working in a crude laboratory at the Darunta terrorist training camp, eight miles south of Jalalabad, al-Masri led a group that experimented with several World War I-era chemical agents, including hydrogen cyanide, chlorine, phosgene, and mustard gas. After the U.S. invasion of Afghanistan in late 2001, U.S. troops searched the Darunta camp and found training manuals detailing the synthesis of nerve agents and how to enhance conventional explosives with toxic chemicals. The following year, CNN broadcast a disturbing al-Qaeda videotape obtained in Afghanistan that showed three dogs being exposed to a toxic gas that appeared to kill them after several minutes. In July 2008, Abu Khabab al-Masri was killed in a U.S. Predator drone strike near the Pakistan-Afghan border, dealing a major setback to al-Qaeda's CW ambitions.

Despite the strong interest in acquiring chemical weapons on the part of al-Qaeda and allied groups, their technical capabilities for production and delivery have remained rudimentary. For example, in February 2003, acting on a tip provided by the CIA, the Saudi Arabian authorities arrested a jihadist cell consisting of five Arab men who were loosely affiliated with al-Qaeda. When the investigators examined the hard drive of a computer owned by one of the men, they found a data file containing plans for a home-made chemical dispersal device called a *mubtakkar* ("invention" in Arabic). This device, which could be built from readily available materials, consisted of a container about the size of a paint can that held two Mason jars filled with liquid hydrochloric acid, surrounded by crystals of potassium cyanide. A detonator and small explosive charge, activated remotely by cell phone, were designed to break open the jars and allow the acid to react with the crystals to generate hydrogen cyanide gas, which is lethal when released in an enclosed space.

The Saudi cell contacted al-Qaeda and proposed using the *mubtakkar* for a terrorist attack on the New York City subway system. Osama bin Laden's deputy Ayman al-Zawahiri personally approved the plan, and the team traveled to the United States in autumn 2002. Six weeks before the planned attack in spring 2003, however, al-Zawahiri called off the operation and ordered the Saudi cell to return home, explaining, "We have something better in mind." As former CIA Director George Tenet noted in his memoir, *At the Center of the Storm*, the subway attack was canceled because it "was not sufficiently inspiring to serve al-Qai'da's ambitions." Indeed, when CIA chemists reconstructed the chemical dispersal device from the plans in the confiscated computer file, they determined that it would not have worked effectively. The acid and the cyanide crystals would have reacted violently, causing the device to blow apart and abort the generation of the lethal gas. Moreover, although hydrogen cyanide is invisible and odorless, the device would have given off a second, more noxious gas called cyanogen chloride, irritating the victims' eyes, throats, and lungs and causing them to flee the subway in search of fresh air before the hydrogen cyanide could reach a lethal concentration.

Individual "lone wolf" terrorists with advanced training in organic chemistry or chemical engineering may also pose a threat. In August 1998, for example, the Moscow police arrested a forty-year-old chemist named Valery Borzov after he attempted to sell a vial of nitrogen mustard (a potent blister agent) to an undercover officer. Borzov had been fired from his scientific research job in 1997 and since then had made a living by synthesizing toxic chemicals in a home laboratory and selling them to the Russian mafia and other criminals for $1,500 per vial. After his arrest, he was diagnosed with schizophrenia, found mentally incompetent to stand trial, and committed to a mental hospital. Although Borzov could produce small amounts of military-grade CW agents, manufacturing them in larger quantities and devising a suitable delivery system would require far greater technical resources and know-how.

Although most terrorist groups that seek a CW capability are still fairly low on the technical learning curve, they could potentially improve their capabilities through a process of trial and error, particularly if they can recruit chemists and chemical engineers who have practical experience working in a state-level CW program. Groups that have developed toxic weapons in the past have typically enjoyed a permissive environment that provided time and space for experimentation. In the case of Aum Shinrikyo, the Japanese police did not take preemptive action against the cult despite clear indications that it was working with toxic chemicals. The reason was that Aum had been officially designated a religion, giving it special legal protections. Similarly, al-Qaeda's physical sanctuary in Taliban-controlled Afghanistan enabled the group to develop and test chemical weapons in secrecy. These cases suggest the importance of denying terrorist groups safe havens, either physical or legal.

Because the prevention of chemical terrorism cannot be guaranteed, effective response and mitigation capabilities are essential, including plans and procedures for the storage, deployment, and administration of medical antidotes and the decontamination of crowds and buildings. The narrow time window for treating exposures to nerve agents (minutes to hours) means that federal response teams would probably arrive too late and would be useful mainly for post-incident decontamination and clean-up. For this reason, state and local hazmat units must be given additional resources and training, along with frequent field exercises. First responders also need better handheld CW agent detectors, portable decontamination showers that can be operated by small crews, and decontamination solutions that are environmentally friendly and less corrosive to the skin. Finally, public-affairs specialists must communicate vital information to the public so that individuals can take steps to minimize their risk of exposure.

## Toxic Industrial Chemicals

In addition to the synthesis of sarin and other military-grade CW agents, possible scenarios for chemical terrorism include the release of toxic industrial chemicals (TICs) such as chlorine, phosgene, arsine, and anhydrous ammonia. Although these chemicals are less lethal than classical warfare agents, they are far more widely available. Dozens of different TICs could potentially be used as weapons, complicating the tasks of identification and treatment, particularly if mixtures are used. Moreover, large volumes of these agents might be released, compensating for their lower toxicity.

TICs could be stolen or diverted from several types of facilities, including chemical or pharmaceutical manufacturing plants, oil and gas installations, semiconductor factories, and even large farms, which use toxic pesticides and anhydrous ammonia as a source of nitrogen fertilizer. Chlorine has myriad industrial applications, including plastics production, water purification, and sewage treatment; in 2008, the global production capacity for chlorine was 62.8 million tonnes. Because of their ubiquity, TICs are relatively easy to acquire. In 2007, for example, investigators from the New York Police Department set up a fictitious water-purification company and ordered large quantities of chlorine over the Internet.

Although the synthesis of military-grade CW agents requires considerable technical expertise, the release of TICs would demand little specialized know-how. Terrorists could steal a pressurized cylinder of toxic gas and discharge it into an enclosed space, such as a subway station or the ventilation system of an office building, or they could use a small explosive charge to punch a hole in a chemical storage tank and release a cloud of toxic agent. The potential consequences of a TIC attack are suggested by industrial accidents involving hazardous materials, which are fairly common and occasionally devastating. The most consequential hazmat incident to date occurred at a Union Carbide pesticide plant in Bhopal, India, in December 1984. Some evidence suggests that this event may have been the result of intentional sabotage. In the middle of the night, water leaked—or was deliberately fed—into a large holding tank of methyl isocyanate, triggering an explosive reaction that led to the release of forty tonnes of highly toxic vapor. The poisonous cloud drifted over a sprawling shantytown adjacent to the plant, kept close to the ground by an atmospheric inversion. Of the large number of people exposed to the chemical, about 100,000 required urgent medical treatment and some 50,000 were hospitalized. An estimated 2,500 victims died immediately and about 16,000 succumbed after a period of months or years. Today, a quarter-century later, thousands of victims of the Bhopal disaster still suffer from chronic ailments.

Even if perimeter and personnel security at chemical plants that work with TICs are bolstered significantly, elements of the transportation infrastructure (such as rail cars, tanker trucks, and barges) may still be vulnerable to attack. In 2005, for example, the derailment of a freight train near the small town of Graniteville, South Carolina, led to the discharge of perhaps as much as sixty tons of chlorine gas, killing nine people and injuring 250 others. The consequences of the deliberate release of a TIC would depend on the characteristics of the agent, the atmospheric and weather conditions, and the population density in the path of the toxic plume. According to data from the Environmental Protection Agency, about a hundred chemical plants in the United States each put one million or more people at risk.

The best defense against chemical terrorism involving TICs is to prevent it from happening in the first place by enhancing the physical security of chemical plants and the associated transportation infrastructure; reducing the quantities of toxic chemicals that are stored and handled at plant sites; and converting industrial processes to less toxic chemicals whenever possible, such as using ozone or bleach instead of chlorine for water treatment and carbonate esters in lieu of phosgene. The transport of TICs also needs to be better regulated. According to Paul Orum of the Center for American Progress, each year railcars carrying chlorine gas travel 300,000 miles throughout the United States, passing through almost all major cities and towns.

Because no strategy of prevention is foolproof, efforts to enhance chemical plant and transportation security must be backed up with capabilities for incident response and mitigation. Real-time computer modeling can predict the geographical area affected by a toxic plume so that public health officials can advise local residents to evacuate or shelter in place. Improving the ability of cities and states to mitigate the consequences of chemical terrorism involving TICs would have the secondary benefit of building capacity to handle ordinary hazmat accidents.

## Conclusions and Recommendations

Despite the successful implementation of the CWC over the past dozen years, chemical weapons remain a serious threat to U.S. and international security and deserve greater attention from policymakers, the news media, and the general public. The CW threat is multifaceted, encompassing military-grade agents, novel incapacitating agents, and toxic industrial chemicals. Moreover, in a world of globalized, flexible chemical manufacturing, countries may decide to hedge their bets by acquiring a standby capability to produce CW agents in a crisis or war. Such "latent" proliferation enables states to break out of the CWC on short notice, creating serious dilemmas for the verification of compliance.

To help prevent the re-militarization of chemistry, the United States and other like-minded countries should take the following steps:

- Increase significantly the budget of the OPCW, which has remained flat at about €74.5 million for the past five consecutive years despite the growing burden of inspections.
- Provide greater political support for the OPCW action plans to achieve universal adherence to the CWC and to ensure effective national implementation of the treaty by all member states. Since the OPCW adopted the action plan on universality in 2003, thirty-three additional countries have joined the CWC.
- Revive the dormant CWC challenge inspection mechanism by using it to clarify ambiguities about compliance, such as whether a particular facility should have been declared, thereby avoiding the political risks of trying to catch suspected violators red-handed.
- Earmark additional funding to accelerate the destruction of U.S. and Russian CW stockpiles in a safe and environmentally responsible manner, so as to complete the task as close as possible to the April 2012 treaty deadline.
- Increase the total number of OCPF inspections per year, while further refining the site-selection algorithm to focus on the multipurpose chemical manufacturing facilities that pose the greatest risk to the CWC.

• Clarify the law enforcement exemption in the CWC to restrict the types and quantities of chemical agents that can be used for counter-terrorism and paramilitary operations.

• Improve the monitoring of global trade in dual-use chemical precursors and production equipment, and support cooperative multinational efforts to track and interdict illicit shipments.

• Strengthen political and economic sanctions on companies and governments that continue to supply CW precursors and production equipment to known proliferators.

• Expand domestic preparedness measures for incidents of chemical terrorism.

Despite the important strides that have been made since the end of the Cold War in reducing the threat of chemical weapons, their total abolition remains a distant goal. At the same time, the emerging political and technological challenges to the effective implementation of the CWC provide grounds for concern. To prevent the chemical disarmament regime from unraveling in the future, the United States and other responsible members of the international community must take urgent steps to strengthen the ban on this largely forgotten class of armament.

**STB Finance Docket No. 35517**

**CF INDUSTRIES, INC. v. INDIANA & OHIO RAILWAY COMPANY, POINT COMFORT RAILRWAY COMPANY, and MICHIGAN SHORE RAILROAD, INC.**

**REPLY COMMENTS**
**OF**
**NORFOLK SOUTHERN RAILWAY COMPANY**

# EXHIBIT 5

AMERICAN ACADEMY *of* ACTUARIES

April 21, 2006

Office of Financial Institutions Policy
Attention: President's Working Group on Financial Markets Public Comment Record
Room 3160 Annex
Department of the Treasury
1500 Pennsylvania Avenue, NW
Washington, DC 20220

Via E-mail to: PWGComments@do.treas.gov

**Re: President's Working Group on Financial Markets: Terrorism Risk Insurance Analysis**

To the President's Working Group on Financial Markets:

The American Academy of Actuaries' Terrorism Risk Insurance Subgroup (Academy subgroup) thanks the President's Working Group on Financial Markets (President's Working Group) for this opportunity to provide comments in response to the request appearing in the Federal Register of March 7, 2006.

## I. Long-term Availability and Affordability of Terrorism Risk Insurance

### 1.1 In the long-term, what are the key factors that will determine the availability and affordability of terrorism risk insurance coverage? How can these factors be measured and projected?

**Academy subgroup response:**

The primary insurance cost issue affecting the availability and affordability of terrorism risk insurance coverage is the potential that a single terrorist attack using weapons of mass destruction could cause a huge aggregate loss from a massive number of individual insurance claims. This potential, combined with the difficulty of estimating the likelihood of such attacks and the difficulty of managing an insurer's exposure to such attacks, creates the possibility (in the absence of any national framework for terrorism



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risk) that insurers could be forced to curtail their writings of important coverages such as workers' compensation in order to manage their exposure to terrorism risk.

Since September 11, 2001 insurers and others have worked to improve their understanding of terrorism risk. This Academy subgroup was formed to make use of this improved understanding to aid policymakers considering the Terrorism Risk Insurance Act of 2002 (TRIA), the Terrorism Risk Insurance Extension Act of 2005 (TRIEA), or other possible national frameworks for terrorism exposure. Unfortunately, this improved understanding of terrorism risk does not supply easy answers to the complicated questions being asked by insurers or by regulators, legislators and other policymakers. Rather, we now better understand the magnitude of the tremendous uncertainties and estimation problems that face insurers, reinsurers, and other potential suppliers of capital that could be used to finance terrorism risk.

If there is no national framework for terrorism risk exposure, some terrorism insurance coverage will probably be available in the marketplace. However, in that case, the massive uncertainties regarding the anticipated frequencies and severities of potential terrorist attacks make it extremely likely that premiums for terrorism risk insurance will be high and volatile, and that availability of terrorism coverage will be limited. If there is no national framework for terrorism risk, coverages such as workers compensation and group life insurance that are required to cover claims caused by terrorists will become much riskier for insurers and thus more expensive and/or less available over time.

Accordingly, the Academy subgroup has concluded that some national framework for terrorism risk is necessary if terrorism coverage is to be widely and readily available.

The remainder of this response to question 1.1 discusses the basis for the Academy subgroup's opinions and conclusions summarized above. Other public statements of the Academy subgroup include its December 1, 2005 public statement on extending or replacing TRIA and its March 29, 2006 testimony to the National Association of Insurance Commissioners (NAIC) public hearing on terrorism insurance matters.

**A. Insurers use special techniques for managing exposure to catastrophes because of the high degree of correlation of such claims, whether the catastrophes are caused by nature or by humans (including events caused intentionally by terrorists).**

Attached to this letter as Appendix I is the executive summary of the American Academy of Actuaries' (the Academy's) June 2001 monograph *Insurance Industry Catastrophe Management Practices*. This monograph is a good resource for understanding how insurers manage their exposure to highly correlated potential claims such as those caused by a hurricane, an earthquake, or a terrorist using a weapon of mass destruction. While the fundamental concepts discussed in this monograph apply to terrorism risk, the monograph was written in the pre-September 11 world and does not itself specifically discuss terrorism risk.

Subsequent to September 11, insurers and others have worked to apply these concepts to the management of terrorism risk. Results of these efforts are discussed below.

**B. Terrorists with access to chemical, nuclear, biological, and radiological (CNBR) weapons of mass destruction have the potential to cause single-event catastrophic insured losses many times the size of the total insured losses from Sept. 11, 2001. Modelers now estimate that terrorists with such weapons could cause insured losses of $700 billion or more, depending on weapon type and location.**

Attached to this letter as Appendix II is a table summarizing the Academy subgroup's insured loss estimates resulting from modeling three different potential terrorist attacks (a large CNBR attack, a medium CNBR attack, and a truck bomb) in four different locations (New York City, Washington, DC, San Francisco, and Des Moines). The Academy subgroup benefited from the assistance of AIR Worldwide in the development of these estimates.

The worst modeled loss (unfortunately, ***not*** a worst case – simply a very bad case) was the large CNBR attack in New York City. Total estimated insured losses were $778 billion which comprised $82 billion for group life insurance and $696 billion for property and casualty (P&C) insurance (including $484 billion for workers' compensation). Modeled losses in excess of $170 billion were estimated for large CNBR attacks in Washington, DC and San Francisco. Modeled losses for a large CNBR attack in Des Moines were over $40 billion, comparable to insured losses from Hurricane Katrina.

The medium CNBR attack resulted in a modeled loss of $447 billion in New York City and close to $100 billion each in Washington, DC and San Francisco. Truck bomb attacks resulted in much smaller modeled insured losses, with the highest being $12 billion in New York City. Unfortunately, it appears more likely that truck bomb attacks may be repeated in various locations. This is no guarantee that CNBR attacks may not be repeated in various locations as well.

Note that if TRIA/TRIEA's "mandatory offer of terrorism coverage" were allowed to expire, insurers could reduce some of these modeled losses by not selling terrorism coverage. However, a substantial majority of the CNBR losses come from the workers' compensation and group life insurance coverages where no terrorism exclusions are allowed. Thus, the only way for insurers to substantially reduce potential workers' compensation and group life insurance losses due to terrorist use of CNBR weapons would be to reduce how much of those coverages they sold at all.

Our responses to questions 1.2 and 1.3 provide more insight into the models used to produce these estimates.

**C. It is important to note that the quantification of policyholder and insurer terrorism exposure required by this analysis is extremely difficult. The probabilities**

**associated with the occurrence of a terrorist attack remain somewhat judgmental and a key source of uncertainty.**

Estimates of the potential losses from terrorist events rely on quantitative approaches that have evolved from those used to estimate the potential insured losses associated with natural disasters. This approach is discussed in more detail in our response to question 1.2.

Estimates of the likelihood of any particular type and location of terrorist attack are much more uncertain and are largely based on expert opinion. The historical record is not much use when considering weapons of mass destruction, because the lack of past terrorist use of such weapons is no guarantee for the future. This issue is discussed in our response to question 1.3.

**D. If TRIA / TRIEA is allowed to expire without replacement or extension, the insurance industry would be exposed to potential insured losses from terrorism far in excess of those it could sustain without significantly damaging its ability to continue providing all insurance coverages, including traditional homeowners and automobile coverages.**

We need to put the potential size of losses into an insurance financial context. The Insurance Information Institute (I.I.I.) reports that policyholder's surplus for the entire property and casualty industry was $414.3 billion as of September 30, 2005. The largest modeled CNBR P&C loss is more than two-thirds higher than the entire property and casualty insurance industry surplus on a pre-tax basis.

There are several issues with this comparison of modeled losses caused by terrorists to industry surplus that should be discussed.

First, the insurance industry as a whole does not pay claims: individual insurance companies do. This means that not all of the insurance industry's capital is available to pay any particular loss. Only the capital of insurers providing coverage triggered by a particular event is relevant. In the case of the largest modeled CNBR event, over 90 percent of the estimated P&C losses were in commercial lines. In this scenario, in the absence of TRIA or some other national framework for dealing with terrorism insurance losses, many commercial lines insurers would be devastated.

Second, these loss estimates are on a primary basis before considering any reinsurance coverage that may be available. However, after September 11, most reinsurance contracts that did not already exclude terrorism coverage were amended to exclude it. The best information we have seen, that provided by the Reinsurance Association (RAA) of America, is that by 2007 perhaps $9 billion of reinsurance coverage for terrorist events may be available to the entire P&C industry, and much of that reinsurance excludes coverage for CNBR events. This amount of reinsurance coverage is not enough to deal with the massive potential insurance losses that could be caused by terrorist events. Please see our response to question 1.6 for further discussion of reinsurance

Third, we need to briefly discuss federal income tax effects. Recall that the P&C losses in our largest scenario were $696 billion of the total $778 billion. On an over-simplified basis, we could calculate the tax benefit associated with the P&C losses in our largest scenario at 35 percent of $696 billion, or $244 billion. Even on that over-simplified basis the after-tax cost of the P&C losses in that scenario would be $452 billion, which exceeds by nearly $40 billion the P&C insurance industry's entire surplus of $414 billion.

The reality is that the actual tax benefits realized by the P&C insurance industry in this scenario would not even begin to approach the calculated $244 billion. Tax benefits only serve to reduce taxes insurers have paid or otherwise would pay on income. Tax loss carry-backs are limited to two years. The entire P&C insurance industry paid about $15 billion of taxes in 2004, according to the I.I.I. At that rate, even making the overly generous assumption that all taxes had been paid by insurers with terrorism losses, only about $45 billion of the $244 billion calculated tax benefit would be available for collection from the Internal Revenue Service from the taxes otherwise owed for the current and most recent two prior tax years.

Tax loss carryforwards are available for a much longer period, but can only be used to reduce future taxes based on the future taxable income of the insurer who generated them. In the absence of TRIA or some other national framework for dealing with terrorism insurance losses, in our scenario many of the insurers with potential tax loss carryforwards would be insolvent and unable to generate future taxable income, so the tax loss carryforwards would expire as worthless.

In summary, if a large CNBR event occurs in the absence of TRIA or some other national framework for dealing with terrorism insurance losses, many commercial lines insurers would be devastated.

**E. Terrorism reinsurance provided by private capital is not able to fill the shortfall the Academy subgroup has identified.**

This key point highlights a portion of the discussion above and our response to question 1.6.

The best information we have seen, that provided by the RAA, is that by 2007 perhaps $9 billion of reinsurance coverage for terrorist events may be available to the entire P&C industry, and much of that reinsurance excludes coverage for CNBR events. This amount of reinsurance coverage is not enough to deal with the massive potential insurance losses that could be caused by terrorist events.

**F. The Academy subgroup believes that the magnitude of potential insurance claims due to terrorist events makes permanent federal legislation necessary in order to make terrorism coverage widely and readily available.**

TRIA/TRIEA caps insurer and government losses (for covered lines) at $100 billion. While the significant increase in insurer deductibles under TRIA/TRIEA means that insurers retain a very large amount of exposure to terrorist events, the cap is very significant when compared to the potential magnitude of losses caused by terrorist use of weapons of mass destruction. We have identified no insurance, reinsurance, or capital markets solution that could finance such potential terrorism losses in the absence of some national framework.

Accordingly, the Academy subgroup believes that the magnitude of potential insurance claims due to terrorist events makes permanent federal legislation necessary in order to make terrorism coverage widely and readily available.

**G. The Academy subgroup believes that there should be a mechanism to develop recommendations for a permanent way of dealing with the risk of terrorism.**

Given the massive size and uncertainty associated with estimates of insured losses from terrorist use of weapons of mass destruction, any mechanism developed to deal with these losses will be extremely influential on the insurance marketplace. The potential for significant unintended marketplace consequences from incidental aspects of the design of such a mechanism is very high. Therefore, a mechanism for developing recommendations that provides significant opportunity for input from insurance experts is important to minimizing the impact of these unintended consequences.

**1.2 What improvements have taken place in the ability of insurers to measure and manage their accumulation of terrorism risk exposures? How will this evolve in the long- term?**

**Academy subgroup response:**

Prior to September 11, few (if any) United States P&C insurers explicitly measured and managed their accumulation of terrorism risk exposures across their whole insurance portfolios. After September 11, insurers realized their need to measure and manage these exposures. The catastrophe risk-modeling firms who already provided tools for measuring and managing P&C insurer portfolio exposures to natural disasters quickly began to develop modifications of these tools designed to address terrorism risks explicitly. Developing these revised tools drew upon engineering studies of weapon destructiveness done for the military as well as expert opinion on the likelihood of varying types and locations of terrorist attacks.

The risk of very large extreme event losses in the face of high uncertainty regarding both frequency and severity has caused insurers increasingly to adopt underwriting tools by insurers to control the likelihood that aggregate losses from a single event will reach unacceptably high levels relative to capital. These techniques are implemented via new modeling techniques for measuring and quantifying various risk exposure measures.

In order to provide the information needed to control exposure to single-event losses, various techniques are used. These include measurement of accumulations of exposure in a single building or potential terrorist target, and accumulations in circular rings around these targets. For workers compensation' and group life insurance, the exposure is often measured in terms of the death benefit in place at the location times the number of insured lives. Accumulations of this nature are all or nothing. They assume total loss within the defined boundary, and they ignore potential losses outside the boundary.

A more precise measure of risk is a modeled loss, or deterministic loss, using a catastrophe model. The response to question 1.1 illustrates examples of modeled industry losses for selected events. Finding an insurer's maximum loss events allows it to manage exposure in those areas. By using a physical damage and injury model, insurers can estimate property damage as well as injuries and fatalities at each location affected. The resulting losses account for weapon characteristics, as well as the construction type and distance of each exposed location from the event location. The estimate includes the appropriate cost for each class of possible injury, from minor to fatality. Deterministic loss analyses can be performed for conventional as well as CNBR attacks.

These information tools allow insurers to fine tune their risk selection process to encourage geographic diversification and discourage excessive concentrations. For workers' compensation and group life, it shows the concentration risk associated with large potential clients.

Rating agencies, as part of their analysis of an insurer's financial strength, have adopted variations of these methods to support the evaluation of terrorism risk management, examining maximum accumulations and modeled losses and their effects on net loss potential.

Full probabilistic modeling is also available from catastrophe modelers. Probabilistic modeling is a standard risk management approach for natural catastrophe risk management. The models present a large array of possible scenarios, and measure the possible losses for each scenario. Thus, the first level of output is a list of the largest possible modeled losses to the company across the range of modeled scenarios. For terrorism, event frequencies are determined through detailed analyses of the favored methods, capabilities, and known objectives of terrorist organizations. It also addresses possible target diversion due to security measures, such as hardening of government facilities resulting in diversion to more accessible private facilities. Based on a comprehensive set of possible events, the analysis results provide an indication of loss potential at various levels of probability. This allows a single measure of a company's risk against a wide range of possible attacks.

The frequency estimates are developed based on expert opinion using open source material,as classified information regarding terrorism threats that may be useful in quantifying near-term risk is not obtainable, nor can it reflect short-term changes in threat level.

Terrorism models differ in comprehensiveness. While all models attempt to capture all possible terrorist attack possibilities, including weapons and attack locations, there may be unanticipated scenarios that are not included.

While these techniques help individual insurers to understand their loss potential and put processes in place to limit exposure through diversification, they do not provide a solution to limit industry loss in the extreme event situations such as the possible multi-hundred-billion-dollar losses described in the response to question 1.1.

**1.3 What improvements have taken place in the ability of insurers to price terrorism risk insurance, including in the development and use of modeling? How will this evolve in the long-term?**

**Academy subgroup response:**

The Academy subgroup response concerns the ability of insurers to estimate costs associated with potential terrorist attacks. Costs are one element considered in an insurer's pricing decision, but pricing per se is outside the purview of this response. This response addresses the development and use of terrorism modeling.

Catastrophe modeling, in general, is based on mathematical representation of potential catastrophes. Models include large catalogs of potential events where the catalog reflects the probability distribution of frequency of events and their parameters. Each event is modeled in terms of the effect on the exposures at risk. A physical model of the event against each building estimates the level of damage, which then results in estimated costs to repair the damage. This represents the severity part of the model. The severity models also include injury components to determine the distribution of injury severities and resulting insurance losses.

For terrorism models, the events are attacks with weapons that may be used by terrorists against potential targets. Target locations come from the types of targets articulated by terrorist groups as being of interest to achieve their goals. Modelers have assembled large databases of such potential targets. Completeness and accuracy verification for target data has been an area of continued development since 2001.

Weapon damage models are largely available due to the engineering and science discipline applied to weapons system engineering over many decades. Modelers have incorporated existing data and models and use new research in that field as it becomes available. The severity portion of models has underlying uncertainty, but it is well understood and treated within the models.

Terrorism models require detailed and accurate exposure data. This means the enumeration of all the properties and lives covered by the insurer. This includes a need for accuracy in the location of properties, description of the physical characteristics, an estimate of the replacement values, and, if applicable, the schedule for the presence of insured individuals. Improvements in the completeness and accuracy of exposure data have been made since 2001, but it is an area needing additional improvement for many insurers.

It is particularly important to note that the modeling of terrorist events included in this set of responses relates primarily to the potential severity of these events. Though there has been some development of probabilistic terrorism models since the September 11th attacks, the quantification of policyholder and insurer terrorism risk is still extremely difficult due to the uncertainty in frequency estimates. Unlike models used to assess natural catastrophe risk, terrorism models cannot rely on past statistical records or on the application of meteorological or geological science. Instead, they must rely on the intellectual capital of experts who have studied terrorist groups to develop assumptions about the potential frequency of terrorist events. While engineering sciences have built a large body of data relating to building damage and peril intensity, the probabilities associated with the occurrence of a terrorist attack remain somewhat judgmental and a key source of uncertainty. For example, in evaluating tornado risk, there is a historical database consisting of thousands of observations of tornados, and there is a similar database with hundreds of hurricane observations. However, for catastrophic terrorism events in the United States, which TRIA was designed to address, there is only one observation.

Compounding the difficulty of this problem, terrorists can adjust their strategies to increase their chances of success against the efforts being made to mitigate terrorist-caused losses. Hurricane or other natural disaster frequencies may change over time, but – unlike the reactions of terrorist groups - they do not change to deliberately avoid our efforts to mitigate the damage they may cause.

For natural catastrophes, it is in the best interest of government to conduct research and disseminate widely the best available information regarding frequency. Modelers readily use this information. For terrorism, intelligence information is collected by the government in a classified environment. Insurers and modelers do not have access to the most complete information regarding frequency. Thus the frequency estimates have additional uncertainty due to the lack of access to this information.

Modelers have provided tools for insurers to measure concentrations of exposure and possible losses in defined scenarios. This information is being used to manage maximum losses. Probabilistic modeling is also available. Average annual loss data from probabilistic modeling has been used as the basis for advisory loss costs for terrorism developed by Insurance Services Office (ISO) that have been used in most of the states. While there is considerable uncertainty in the frequency estimates, relative loss estimates across locales have provided credible estimates of relative risk useful in portfolio management based on our current understanding of the terrorist threat.

One of the most important contributions of the terrorism modeling efforts has been the identification of potential attack scenarios using CNBR weapons that could cause insured losses of many hundreds of billions of dollars. While these scenarios represent the tail of the probability of loss distribution (high potential loss, low frequency), their existence demands that risk management be applied in case such events occur. These events are hundreds of times more severe than the modeled average annual loss. Even if these assessments of frequency or severity were varied substantially, the magnitude of the potential losses from these events far exceeds the ability of the industry to cover them.

The events of September 11 made it clear to the insurance industry that there is considerably more uncertainty concerning potentially significant losses due to terrorism than most industry participants had previously been aware. Reactions of participants in the industry, starting with the almost immediate and almost complete disappearance of voluntarily sold reinsurance coverage for terrorist events, were key factors motivating the TRIA legislation in 2002.

As is noted in this discussion, something has been learned since September 11 about modeling an insurer's exposure to catastrophic losses caused by terrorism, but that knowledge is less complete and more uncertain than our knowledge about other types of catastrophic losses.

**1.4 How, if at all, were primary insurers' pricing decisions affected by the anticipated expiration of TRIA at the end of 2005, particularly for insurance policies extending into 2006 that cover terrorism risk? What role did the pricing and availability of reinsurance play in those decisions?**

**Academy subgroup response:**

Again, the Academy subgroup's response to this question concerns anticipated costs associated with terrorism risk which is an important element of pricing decisions. Individual insurer pricing decisions are outside the scope of the Academy subgroup's response.

The following illustrative examples of coverage and cost options available to insurers facing the expiration of TRIA are based upon materials produced by ISO, an advisory organization for loss costs and policy forms.

In anticipation of the termination of TRIA at the end of 2005, options for conditional exclusions and limitations were made available to insurers before the 2005 policy year.

There were three versions of the conditional forms -- total exclusion of conventional weapon terrorism above a $25 million event threshold (but with no threshold on CNBR events); exclusion of CNBR terrorism only; sub-limit on terrorism above a $25 million event threshold, subject to underlying policy provisions. The conditional provisions were structured to limit terrorism coverage under the policy in the event of termination of TRIA or extension of TRIA without a mandatory participation requirement and with a backstop less favorable to the insurer. The conditional forms were approved in 51 of 54 jurisdictions (not approved in Florida, Georgia and New York).

Advisory rating information was made available to insurers in support of the aforementioned conditional options, as well as for the option of covering terrorism subject to underlying policy provisions. The advisory rating information was provided for TRIA program years and for the post-TRIA period. Post-TRIA advisory rating information recognizes the absence of federal participation in losses. Since rating took place before the fate of TRIA was decided, rating options enabled development of a provisional premium that could have entailed additional or return premium upon the termination or extension of TRIA.

The same conditional options and rating options are being made available for the anticipated end-of-2007 termination.

**1.5 What role do mitigation efforts related to terrorism risk play in an insurer's underwriting and pricing decisions? How will this evolve in the long-term?**

**Academy subgroup response:**

Insurance mechanisms identify and place a cost on risk. Ideally, successful insurance systems will reward loss mitigation activities with premium reductions commensurate with the expected cost reductions due to mitigation. By comparison, the premium for unmitigated activities will be higher. There are several examples of mature insurance systems which provide strong mitigation incentives to the market. Workers' compensation has developed an extensive risk classification system, a sophisticated experience rating plan, and retro plans to provide a clear relationship to the insured between potential losses and premium costs. Homeowners insurers in areas prone to catastrophes provide incentives and discounts for structures built to comply with stronger building codes or that have been retrofitted to withstand hurricanes or earthquakes. These systems are successful because the insurance system has accumulated a large volume of information on the effect of various mitigation activities that protect against threats which are stable over time, so that insurer premiums send economic signals to insureds on the benefits of particular mitigation activities.. Insureds then have an economic incentive to invest in mitigation, lowering overall losses to the system.

Terrorism poses unique challenges that make it far more difficult for insurers to fine tune underwriting and pricing practices to reflect mitigation activities. Insurers lack the type of detailed data on the effect of mitigation measures available in other lines. Further, terrorists can change their behavior to defeat mitigation efforts in ways natural disasters cannot. (A hurricane will not change course to avoid an area with homes built to code.) These factors make it more difficult for the insurance system to encourage mitigation to the same extent it can in other lines of business.

Insurer clients may employ terrorism risk mitigation strategies, such as placing concrete barriers in front of trophy targets to discourage truck bombs. The insurance system will take such information into account when underwriting and pricing risks. The existence or lack thereof of a federal terrorism program should not interfere with the private market's incentives to encourage mitigation. The large retention and financial exposure that insurers retain under TRIA and TRIEA provide incentives to encourage mitigation.

In the long term, the evolution of understanding of which mitigation efforts are effective will allow for more refined underwriting and pricing. Unfortunately, the nature of the terrorist threat makes it much more difficult to provide strong mitigation incentives in many locations. For example, the threat of terrorist activity in a small midwestern town might currently be perceived as low, meaning that the insurance system might not provide strong economic incentives for expensive investments in mitigation. However, terrorist strategies might change much more rapidly than the insurance system could react. Contrast this to a natural disaster, where there is a fairly clear way of identifying places prone to loss that does not change radically from year to year.

**1.6 What is the current availability of reinsurance to cover terrorism risk? Please distinguish by line or type of insurance being reinsured and on what basis (treaty or facultative). How will this evolve in the long-term?**

**Academy subgroup response:**

The Academy subgroup is not in a position to provide a specific market analysis of reinsurance. We can, however, offer several general observations.

First, we have seen no evidence that there exists private reinsurance capacity to address the type of extreme events the Academy subgroup has modeled (See response to question 1.1). Several of those events are an order of magnitude larger than reported reinsurance capacity even under TRIA or TRIEA. Without a national framework for terrorism insurance, certain modeled events could be two orders of magnitude greater than reported reinsurance capacity.

Second, standard reinsurance contract language often excludes terrorist acts covered by TRIA or the 2005 extension, and all "biological, chemical, or nuclear pollution or contamination."

Reinsurance markets face the same difficulties as primary insurers in pricing coverage in terms of the state of the art of catastrophe modeling tools. Currently, some observers have suggested that the catastrophe risk modeling tools for natural disasters could be improved, based on the model's projections in advance of the actual 2004 and 2005 hurricane seasons. The available terrorism models are subject to more uncertainty that those for hurricanes. Thus, in the short term reinsurers face significant challenges in quantifying their exposure to terrorism losses. This reinsurer uncertainty will serve to limit available capacity.

In the long term, the amount of private reinsurance capacity will be related to the confidence that the markets develop in their pricing tools and their understanding of the risk. It would require a very significant increase in capacity for the private market to absorb the risk now covered by TRIA even under TRIA's $100 billion cap. Given current market conditions in the wake of recent hurricanes, it is difficult to see how the markets will be able to generate significant additional terrorism reinsurance capacity in the short term. Substantial capital has been raised to replace reinsurance capital lost to the hurricanes of 2005, but little, if any, of that capital is available to cover terrorism risk.

One final consideration is the degree of stability public policy makers want for consumers. Reinsurance markets are subject to short-term disruption manifested as decreased reinsurance availability and substantially increased cost. This is occurring now with regard to property catastrophe reinsurance. Terrorism reinsurance markets may be subject to even greater short-term instabilities due to the uncertain nature of the terrorist threat and the enormous potential magnitude of losses. While the Academy subgroup takes no position on what value public policy makers should place on market stability, we do note that there are several other examples of government frameworks designed to address financial market instability, such as the Federal Reserve System.

**1.7 At what policyholder retention levels are insurance programs being structured to cover terrorism risk; and, with regard to insurers, how are reinsurance programs likewise being structured? Please comment on the availability and affordability at each level.**

**Academy subgroup response:**

Details of actual agreements reached in the marketplace are outside the scope of the Academy subgroup's response.

**1.8 In the long-term, what are the key factors that will determine the amount of private-market insurer and reinsurer capacity available for terrorism risk insurance coverage? How will this evolve in the long-term? Please comment on potential entry of new capital into insurance markets.**

**Academy subgroup response:**

Conceptually, the factors discussed in our response to question 1.1 apply to reinsurers as well as insurers. In the absence of a national framework for terrorism risk, reinsurance for terrorism risk is likely to be volatile, expensive, and of insufficient quantity.

There is one significant difference between the reinsurance and insurance marketplaces in the terrorism insurance context. Reinsurance coverages in general are not mandated by law or regulation to cover any particular perils. Thus, reinsurers are free to draft contracts that exclude coverage for claims their primary company clients must pay. On the one hand, this allows the reinsurers more power to manage their exposures, as their basic business model tends to attract substantial concentration risk. On the other hand, this means that primary companies cannot rely on laying off risks they may have felt "forced" to take on.

Again assuming the lack of a national framework for terrorism risk, note that we see no prospect, even in the long term, of a significant reduction in the uncertainty associated with estimating terrorism exposure. Accordingly, we see no prospect of any rapid increase in the amount of private capital invested in terrorism risk reinsurers.

**1.9 To what extent have alternate risk transfer methods (e.g., catastrophe bonds or other capital market instruments) been used for terrorism risk insurance, and what is the potential for the long-term development of these products?**

**Academy subgroup response:**

The Academy subgroup's responses have benefited from the expertise of AIR Worldwide. AIR Worldwide has directly supported a large portion of the transactions for raising risk capital through catastrophe bonds, and has modeled virtually all of the catastrophe bonds ever issued as part of services provided to investors. This response reflects knowledge obtained through those experiences.

As far as we are aware, the financial industry has not yet issued a cat bond (or individual tranche) solely on the basis of terrorism risk. (The FIFA World Cup bond covered the potential cancellation of the event, which could be caused by a number of possibilities, terrorism being only one.) We have heard skepticism from both rating agencies and investment banks about the market being ready for a terrorism bond.

Catastrophe bonds involve participation by several parties. Investors offer capital seeking a diversification from market risks and potentially a higher return in exchange for added risk. Quantification of the risk is of utmost importance. Like reinsurance contracts, pricing is based on detailed probabilistic loss analysis. Risk for catastrophe bonds is quantified by catastrophe modeling companies. Bonds are rated by rating agencies. This includes evaluation of the models and the quality of the data used in the models.

Investors do not generally have the risk analysis expertise for extreme events that is resident in insurance companies and reinsurance companies. Therefore, they look to the practices and risk assessments used by those companies as well as the ratings provided by the rating agencies for guidance. The rating agencies have indicated no willingness to use probabilistic terrorism loss models for ratings.

Citing the same risk uncertainties cited by insurers and reinsurers regarding terrorism, as well as the fact that terrorism catastrophe bonds are not able to be rated, investors have expressed little appetite for such investment vehicles to date.

Thus, the issues limiting the availability of reinsurance for terrorism also limit the use of alternative risk transfer methods.

**1.10 To what extent have captive insurance companies been used for terrorism risk insurance, and what is the potential for the use of captive insurers to insure against such risk long-term?**

**Academy subgroup response:**

The Academy subgroup is not aware of any captive that has been set up specifically to provide terrorism coverage.

TRIA and TRIEA require the offer of terrorism insurance on the same terms and conditions as for other perils covered by policies in the lines of insurance subject to these acts. To the extent a captive is subject to the TRIA/TRIEA mandatory offer provisions, and their insureds (owners) opt for the coverage, the captive is required to provide such coverage and is covered by the federal backstop.

An entity whose purpose is to cover the exposure of a single entity will need the availability of some mechanism to share/spread that risk. This is especially true for a catastrophic exposure. In the absence of readily available reinsurance, an aggregate cap and/or a pooling arrangement (such as might be provided under a national framework for terrorism risk), it is unlikely that captives would be set up specifically to provide terrorism coverage.

Note, however, that while TRIA/TRIEA is in effect, a captive that had already been set up to handle workers compensation exposure could have access to recoveries for terrorism losses at levels considerably lower than had the same premium been written through a standard insurer. This happens because the standard insurer's terrorism deductible is increased due to other workers compensation premium it writes and to premium it writes in other lines covered by TRIA/TRIEA.

**1.11 Have state approaches made coverage more or less available and affordable, such as through permitted exclusions and rate regulation? To what extent will the long-term availability and affordability of terrorism risk insurance be influenced by state insurance regulation? Please comment on state approaches to ensure the continued availability and affordability of terrorism risk insurance in the absence of the TRIA Program being in- place (include state approaches after September 11, 2001 and before TRIA became law on November 24, 2002, as well as state approaches in preparation for the expiration of the TRIA Program).**

**Academy subgroup response:**

TRIA and TRIEA mandate that terrorism insurance coverage be made available for covered lines, so that state actions currently have no impact on the availability of terrorism coverage for such lines.

Some states have disapproved original insurer terrorism rate filings and later approved those filings when the rates had been reduced. Given the requirement of mandatory offer, such a state action has the effect of making terrorism insurance coverage more affordable than it would otherwise be.

However, on expiration without replacement of TRIA and TRIEA, insurers would no longer be required to offer terrorism coverage to every client for the underlying coverage. In such a case, state terrorism rate disapprovals could operate to reduce, perhaps considerably, the availability of terrorism insurance.

Note also that certain coverages, such as workers' compensation, may be defined by state law in a manner that implicitly or explicitly provides for coverage of the peril of terrorism. In such a case, an insurer wishing to limit its accumulation of terrorism exposure would have no tool to do so other than avoiding the underlying exposure (workers' compensation in this case).

If a state did not approve exclusions for terrorist attacks not covered by TRIA/TRIEA, such a state action could expose insurers to very large losses and as in the workers' compensation example above potentially affect the availability of the underlying non-terrorism coverage. A state's failure to approve terrorism exclusions could affect the financial solidity of the insurer.

**1.12 What are the differences in availability and affordability of terrorism risk insurance between the licensed/admitted market and the non-admitted/surplus lines market, and, if so, to what degree are those changes attributable to the degree and manner in which each market is regulated?**

**Academy subgroup response:**

Given the "mandatory offer" provision of TRIA/TRIEA, there can be no "availability" problem for terrorism risk insurance for risks written by either market.

**1.13 What are the differences in availability and affordability of terrorism risk insurance coverage for losses at US locations as compared to such coverage for losses at non-US locations?**

**Academy subgroup response:**

The Academy subgroup has no information with which to make a response to question 1.13.

## II. Long-term Availability and Affordability of Group Life Insurance Coverage

**2.1 What impact, if any, does terrorism risk have on the availability and affordability of group life insurance coverage to the policy holder (e.g., employer) and certificate holders (e.g., employees)? How will this evolve in the long-term?**

**Academy subgroup response:**

The Academy subgroup is unaware of any significant current impact of terrorism risk on the availability and affordability of group life insurance for policyholders and certificate holders. However, we believe it is quite possible that there will be a significant long-term impact. The lack of current impact exists for several reasons.

First, the unique nature of terrorism risk means that it is very difficult to quantify the risk or to determine appropriate pricing actions. Little historical data is available due to the scarcity of large-scale attacks, and while it is possible to make some estimates of the potential severity of terrorist attacks for very specific scenarios, projecting the frequency of such attacks is considerably more uncertain. Group life has historically been inexpensive relative to the other coverages it is commonly marketed with. Insurers may well be concerned that even modest price increases could have a material impact on the decision to purchase this coverage, since many employers might opt to reduce or eliminate their group life plans instead of paying the higher premiums. Group life insurers are concerned about reducing the group life market by increasing premiums based on essentially one event (September 11), even though the potential of additional events is well established.

Second, the consumer impact of terrorism risk on the group life insurance industry will emerge more slowly than in the property/casualty industry for many reasons:

- Property/casualty insurers were hit harder than group life insurers by the events of September 11, creating a greater sense of urgency for immediate action.

- Group life mortality has historically been quite stable, and group life insurers are accustomed to pricing and managing their business through the analysis of long-term trends. They are hesitant to disrupt their market by raising premiums and restricting availability in response to a single catastrophic terrorist event, when the probability of recurring events is so difficult to predict. Many carriers may feel that, in the absence of catastrophe reinsurance for terrorism, their only other option to deal with terrorism risk is to exit the group life business at tremendous opportunity cost as discussed below.

- Group life is a relatively small portion of the overall employee benefit market, which includes coverages such as disability, dental, medical, and pensions. Group life insurers may fear that a sudden change to the premiums or benefits for their group life business could cause employers to seek other carriers not only for their group life business, but also for these other, larger, product lines.

Because group life insurers are not permitted to offer coverage with terrorism exclusions and have a very difficult task in estimating the cost of the terrorism risk, they have perceived their choice as either (1) continuing to provide coverage for terrorism without collecting adequate premium for the true cost of terrorism risk, (2) ceasing to offer coverage to those market segments perceived to be at a high risk for terrorism, or (3) exiting the group life market entirely. Companies dislike exiting markets, and the process poses significant regulatory, financial, and public relations challenges. Once such a decision has been reached, however, it is even more difficult for a company to re-enter a market, because it will no longer have the distribution network, the infrastructure, or the market credibility it had before its exit. As a result, company decisions to exit the group life market will be taken slowly. However, in the absence of some risk-sharing mechanism, some companies will seriously consider such a step, especially if major terrorism costs were to occur again.

**2.2 To what extent is an insurer's decision to issue group life coverage influenced by aggregation or accumulation risk in certain locations? What steps have group life insurance providers taken or do they plan to take to offset any aggregation or accumulation risk?**

**Academy subgroup response:**

The aggregation of risk in certain locations is a fundamental characteristic of group life insurance because the groups insured are commonly employees of a company whose workdays are concentrated in one or a few physical locations. Since the events of September 11, many companies have begun paying much closer attention to the concentration of risk in their group life business. According to a 2005 LIMRA International (LIMRA) survey on the group life catastrophe reinsurance market, approximately one-third of responding companies indicated that they had restricted coverage to some groups based on location. Specific examples cited by the respondents include major metropolitan areas such as New York, Chicago, and Washington, DC, as well as high-profile buildings in those and other locations. In addition, some groups with an industry or occupation that will have a higher probability of being involved in the response to a terrorist attack (police/fire) are being restricted or declined by some insurers. Although such underwriting declinations have been infrequent, we understand they have occurred.

**2.3 Has terrorism risk made group life coverage less affordable to the policy or certificate holder? Have group life insurance rates increased or decreased as compared to rates before and since September 11, 2001?**

**Academy subgroup response:**

As indicated in the response to question 2.1, there is little evidence to suggest that group life has become less affordable to the policy or certificate holder as the result of terrorism risk, although it is likely that this is true for isolated cases. According to data published by the American Council of Life Insurers (ACLI) for the entire group life insurance industry, the average rate per $1000 of coverage decreased from $4.18 in 2001 to $3.49 in 2003, and then increased to $3.63 in 2004. It is not possible to isolate the impact of terrorism risk on these premium changes, which are also heavily affected by factors such as the distribution of product types (e.g., whole life versus term life) and mortality trends other than terrorism.

**2.4 Please explain how group life insurance coverage may be bundled with other coverages and benefits provided through an employee-benefits program, and how group life coverage is priced, either separately or collectively, through such programs. Please describe any effects competition has on such pricing.**

**Academy subgroup response:**

It is extremely common for group life to be sold in conjunction with several other group products including long term disability, short term disability, dental, and medical. Surveys have shown that most carriers will offer a discount on their group life rates if the products are sold in conjunction with other products. There are several justifications for this:

- improved persistency,
- less selection risk if an employer is looking for multiple coverage versus stand-alone life,
- sales goals on the other group products that are sometimes less marketable,
- expense savings as some limited economies of scale are achieved in policy issuance and maintenance.

Prices are adjusted only for package discounting at the employer level, never at the employee level. For example, in a voluntary setting the group life rates are the same for all employees regardless of how many different product types they buy. Competition is the main driver for the third point above. Potential employer clients who lack these employee benefits are increasingly rare. The market has hit a maturity stage where an insurer that wants to increase its market share must effectively decrease a competitor's market share. The importance of obtaining several product lines on a single group becomes enormous. It is also the reason that profit margins have stayed extremely thin on group life, whose results are typically very stable, but potentially extremely volatile.

**2.5 Are group life providers voluntarily providing coverage for loss of life arising out of or resulting from acts of terrorism, or is coverage mandated by any state or**

**federal laws? Are group life providers prohibited by law from excluding terrorism risk from group life insurance policies?**

**Academy subgroup response:**

The Academy subgroup understands that group life insurers provide coverage for loss of life from terrorism because no exclusion for this coverage is or has been allowed, whether by operation of state insurance laws (e.g., California) or by state insurance regulatory decisions.

**2.6 Has terrorism risk affected segments of the group life market differently, such as in the case of small/medium sized employers, and if so, why?**

**Academy subgroup response:**

The Academy subgroup does not have market information that pertains to the treatment of small or medium sized employers.

As described in the response to question 2.2, the LIMRA survey on catastrophe reinsurance indicated that terrorism risk has had a greater impact on customers in large metropolitan areas and high profile buildings. One respondent to the survey also indicated that it had placed some underwriting restrictions on the availability of group life insurance to "first responders" such as police and fire personnel.

**2.7 In the long-term, what are the key factors that will determine the availability and affordability of terrorism risk insurance coverage for group life insurance?**

**Academy subgroup response:**

In the long run, the availability of meaningful and affordable catastrophe reinsurance coverage for group life insurers will be a key factor in determining the availability and affordability of group life insurance (which, by law or regulation, may not exclude coverage for terrorism risk) for consumers. The LIMRA survey showed that, more than four years after the events of September 11, 2001, there is still insufficient catastrophe reinsurance capacity (even including pooling arrangements) to protect insurers against large-scale terrorist attacks. The widespread availability of catastrophe reinsurance before that date meant that the losses from that event were spread efficiently among a large number of insurers and reinsurers. The decreased use of catastrophe reinsurance coverage today, due to availability and affordability issues, means that a single terrorist attack could pose solvency issues for group life insurers, and could lead many companies to stop offering group life insurance altogether.

In other words, it appears likely that group life insurance that covers terrorism risk could become substantially less available and less affordable, assuming group life insurance remains outside any national framework for terrorism risk. Group life insurance was covered neither by TRIA or by TRIEA, and at some point group life insurers may stop acting as if it were.

**III. Long-Term Availability and Affordability of Insurance Coverage for Chemical, Nuclear, Biological, and Radiological (CNBR)~ Events caused by Terrorism**

**3.1 What is the current availability and affordability of coverage for CNBR events, and for what perils is coverage available, subject to what limits, and under what policy terms and conditions? Is there a difference in the availability and affordability of coverage for CNBR events caused by acts of terrorism?**

**Academy subgroup response:**

TRIEA clearly provides that coverage for terrorism is subject to the terms and conditions of the underlying policy. Thus, under the current federal program, coverage for CNBR events caused by terrorists depends on whether the underlying policy would have covered the peril even absent terrorist involvement.

Under commonly used workers' compensation and group life policies, no exception applies to the applicability of coverage if the loss is due to a CNBR event. Such coverage would be available up to the full limits of the policy.

For property policies, the situation is more complicated. Commonly used property policies have various provisions that exclude coverage for nuclear reaction, radiation or contamination. However, damage from certain perils (fire, for example), that results from a nuclear reaction, may be covered. Regarding coverage for biological and chemical events, property policies often contain specific exclusions that could apply in the event of a terrorist attack involving these perils that would bar coverage. Whether coverage applies would depend on the specific facts associated with a particular loss event and the coverage stipulations included in the policy. If such coverage is found to apply it would usually be available up to the full limits of the policy.

For liability coverage, also, whether coverage applies in the event of a CNBR attack would depend on the coverage stipulations included in the policy and the specific facts associated with the event.

In a post-TRIEA environment, insurers would have available specific endorsements to exclude coverage for CNBR events initiated by terrorists. Industry use of such endorsements would reflect each insurer's evaluation of the risk/reward trade-off associated with coverage of this peril.

**3.2 What was the general availability of coverage for CNBR events prior to the terrorist attack of September 11, 2001? To what extent, subject to what limits, and for what perils was coverage available? Did it cover acts of terrorism?**

**Academy subgroup response:**

Before September 11, if the underlying policy provided coverage for these perils, losses from these perils caused by terrorists were often not excluded.

In particular, workers' compensation coverage generally included all perils that could injure workers on the job, so insurers were implicitly providing CNBR coverage.

Note, however, that although contractually insurers were providing this coverage in many cases, it was not being provided on an intentional basis. Before September 11, insurers gave little consideration to the possibility of terrorist acts that could cause insured losses of the magnitude that now appears possible.

**3.3 If coverage for CNBR events caused by acts of terrorism is available, please describe generally to what extent (i.e., limits, locations, exclusions, etc.) for what kinds of insurance and from what types of insurers (i.e., large/ small, admitted/surplus lines, etc.). How will this evolve in the long-term?**

**Academy subgroup response:**

Again, for lines of business covered by TRIA and TRIEA, insurers are mandated to make available coverage for losses caused by foreign terrorists for the same perils covered by the underlying policy.

We interpret the question about the long-term to require an assumption that TRIA and TRIEA expire without replacement. In such a case, and given the small amount of reinsurance coverage available for CNBR events, insurers may be forced to manage their terrorism exposure without the benefit of either reinsurance or a national framework (including the $100 billion cap on insured terrorism claims) for insured terrorism risk. In such a scenario, it appears likely that insurers will only be able to attain acceptable levels of risk exposure by providing considerably less coverage for terrorism risk than they are providing today.

**3.4 To what extent is terrorism risk coverage available and affordable for nuclear facilities and for chemical plants, manufacturers, and industrial chemical users?**

**Academy subgroup response:**

Details of actual agreements reached in the marketplace are outside the scope of the Academy subgroup's response.

**3.5 To what extent, both prior to and since September 11,2001, have various states allowed insurers to exclude coverage for CNBR events? Please comment on requirements for workers' compensation and fire-following coverage.**

**Academy subgroup response:**

Again, workers' compensation is generally defined by state law to provide coverage for all perils so that no CNBR exclusions have been allowed. Please see our response to question 3.1 for further discussion of the availability of coverage for CNBR events.

**3.6 It appears that some insurers are unwilling to provide coverage for CNBR events caused by acts of terrorism even with the federal loss sharing provided by the TRIA Program. Why would this be the case given that TRIA limits an insurer's maximum loss exposure?**

**Academy subgroup response:**

Individual insurer decisions to offer or not offer coverage are beyond the scope of the Academy subgroup's response.

We will note, however, that insurers writing workers' compensation and group life insurance are currently providing large amounts of coverage for CNBR events. Please see our response to question 1.1 for more information on the magnitude of such coverage.

We will also note that under TRIA/TRIEA individual insurer terrorism deductibles can be very large. Where insurers have the option not to provide CNBR coverage on the underlying policy, they may evaluate the potential premium for providing CNBR coverage as incommensurate with the exposure being taken on.

**3.7 In the long-term, what are the key factors that will determine the availability and affordability of terrorism risk insurance coverage for CNBR events?**

**Academy subgroup response:**

CNBR events can cause the largest losses due to terrorism risk as discussed in our response to question 1.1.

Given the magnitude of potential claims due to CNBR events and the tremendous uncertainty associated with evaluating the likelihood of such events, there are essentially two long-term scenarios.

1. Absence of a national framework for terrorism insurance: In this case there is likely to be a limited and volatile market for terrorism coverage for CNBR events. To the extent state laws and regulations mandate inclusion of coverage for CNBR events caused by terrorists, these requirements are likely to reduce availability of standard coverages. Even so, a terrorist attack using CNBR weapons in this scenario has the potential to cause massive insolvencies of standard insurers, complicating the task of

national recovery from such a devastating event.

2. With a national framework for terrorism insurance: If properly designed, a national framework would allow terrorism coverage to be widely available. While the underlying uncertainty about the frequency and severity of terrorist events would remain, the volatility of premiums for this coverage given a national framework should be considerably less that in the above scenario.

The Academy subgroup would be glad to provide further assistance or additional information to the President's Working Group upon request.

Very truly yours,

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Attachments (2 Appendices)

## AMERICAN ACADEMY OF ACTUARIES

The American Academy of Actuaries is a national organization formed in 1965 to bring together, in a single entity, actuaries of all specializations within the United States. A major purpose of the Academy is to act as a public information organization for the profession. Academy committees, task forces and work groups regularly prepare testimony and provide information to Congress and senior federal policy-makers, comment on proposed federal and state regulations, and work closely with the National Association of Insurance Commissioners and state officials on issues related to insurance, pensions and other forms of risk financing. The Academy establishes qualification standards for the actuarial profession in the United States and supports two independent boards. The Actuarial Standards Board promulgates standards of practice for the profession, and the Actuarial Board for Counseling and Discipline helps to ensure high standards of professional conduct are met. The Academy also supports the Joint Committee for the Code of Professional Conduct, which develops standards of conduct for the U.S. actuarial profession.

## Terrorism Risk Insurance Subgroup

*Michael G. McCarter, FCAS. MAAA, Chair*

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**George Burger, FCAS, MAAA**
**Cecil D. Bykerk, FSA, MAAA**
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**Daniel D. Skwire, FSA, MAAA**
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The Subgroup recognizes Jack Seaquist and Jeremiah M. Downing, CPCU, for their participation in the development of these responses. The Subgroup thanks AIR Worldwide Corporation and ISO for the provision of modeling and technical resources used in preparing these responses.

**First attachment for response to question 1.1**

# Insurer Catastrophe Management Practices

Following are the bullet points from the Executive Summary of the monograph entitled "Insurance Industry Catastrophe Management Practices". The complete monograph is available on the Academy website, www.actuary.org.

- Catastrophe exposures place special demands on insurer capitalization and require a distinct risk management approach. The risk management process for an insurer must integrate all risk management strategies of the insurer, not just a single risk, such as catastrophe risk. The interaction or covariance (versus independence) of the various risks a company faces is an important factor in determining the company's total capital requirements.
- For property and casualty insurers, catastrophes are defined as infrequent events that cause severe loss, injury, or property damage to a large population of exposures.
- Whereas most property insurance claims are fairly predictable and independent, catastrophe events are infrequent and claims for a given event are correlated. The insurance process, if left unmonitored during lengthy catastrophe-free intervals, could produce increasing concentrations of catastrophe exposure.
- Catastrophes represent significant financial hazards to an insurer, including the risk of insolvency, an immediate reduction in earnings and statutory surplus, the possibility of forced asset liquidation to meet cash needs, and the risk of a ratings downgrade.
- Insurers manage catastrophe risk through a continuous learning process that can be described in five steps. The steps are identifying catastrophe risk appetite, measuring catastrophe exposure, pricing for catastrophe exposure, controlling catastrophe exposure, and evaluating ability to pay catastrophe losses.
  - **Identifying catastrophe risk appetite** - An evaluation of catastrophe risk appetite gives underwriters a guideline for determining whether catastrophe risk in the insured portfolio is within acceptable limits.
  - **Measuring catastrophe exposure** - The objective of measuring catastrophe exposure is to be aware of the company's current exposure to catastrophes, both in absolute terms and relative to the company's risk management goals.
  - **Pricing for catastrophe exposure** - In setting rates for catastrophe insurance coverage, the general trend is away from using a long historical experience period, toward the application of catastrophe models to current or anticipated exposure distributions. The shortcomings of using historical premium and loss experience are clear, and catastrophe modeling has been widely adopted in making rates for hurricane and earthquake.

**Appendix I**

- ➢ **Controlling catastrophe exposure** - For various reasons, insurers may decide they have a need to control or limit catastrophe risk. Usually this results in reducing exposure in segments where capacity is exceeded, and using reinsurance or capital market instruments to transfer exposure to someone else.
- ➢ **Evaluating ability to pay catastrophe losses** - Catastrophe claim payments are funded through normal operating cash flow, asset liquidation, debt financing, or advance funding from reinsurers.

- Actuarial standards exist for appropriate application of catastrophe models. Also, to help regulators evaluate use of the models in making rates, the Catastrophe Insurance Working Group of the NAIC published the *Catastrophe Computer Modeling Handbook* in January 2001.
- Generally, the liquidity (or illiquidity) of an insurer after a catastrophe does not cause insolvency. Rather, it is the magnitude of the event relative to company surplus. Insurers must strike a balance between the benefits of being prepared for low-probability catastrophes and the cost of pre-event preparations.
- There is no one catastrophe risk management procedural template that applies to all insurers. However, the conceptual elements are the same for any property and casualty insurer.
- Reinsurance is the traditional method used by insurers to transfer risk, but capital markets are a growing source of alternate capacity. Capital market products developed to date can be grouped into three categories: insurance-linked notes and bonds, exchange-traded products, and other structured products.
- Catastrophe risk management for reinsurers is similar to that of a primary company. For a reinsurer, the challenges are to obtain adequate catastrophe exposure information from ceding companies, to accurately measure catastrophe exposure aggregations across multiple ceding companies, and to price for the exposure.
- Insurer catastrophe risk management practices are relevant to certain questions of public policy. Examples include the amount of insurer capital, whether insurer capital needs to be segregated for catastrophe purposes, whether to encourage pre-event funding, the tradeoffs between availability and affordability, the extent of governmental involvement in the market place, and potential over-reliance on guaranty funds.
- Policy-makers considering actions designed to affect either catastrophe coverage availability or the solvency of insurers exposed to catastrophe claims can use the five step catastrophe risk management approach to anticipate market effects of the proposals they are considering. Generally, policy actions have more than one consequence, and this framework can help to anticipate secondary (and sometimes unintended) consequences.

Appendix II

**Second attachment for response to question 1.1**

The following table summarizes the modeled terrorism events discussed in the testimony of the American Academy of Actuaries Terrorism Risk Insurance Subgroup. The loss estimates are pre-tax and before any reinsurance considerations.

***Summary of Results*** **– Insured Loss Estimates in $Billions**

| Scenario | Line of Business | New York City | Washington, DC | San Francisco | Des Moines |
|---|---|---|---|---|---|
| Large CNBR | **Total** | **778.1** | **196.8** | **171.2** | **42.3** |
| | Auto | 1.0 | 0.6 | 0.8 | 0.4 |
| | Commercial Property | 158.3 | 31.5 | 35.5 | 4.1 |
| | Residential Property | 38.7 | 12.7 | 22.6 | 2.6 |
| | Workers' Compensation | 483.7 | 126.7 | 87.5 | 31.4 |
| | General Liability | 14.4 | 2.9 | 3.2 | 0.4 |
| | Group Life | 82.0 | 22.5 | 21.5 | 3.4 |
| Medium CNBR | **Total** | **446.5** | **106.2** | **92.2** | **27.3** |
| | Auto | 0.2 | 0.1 | 0.2 | 0.1 |
| | Commercial Property | 77.8 | 15.7 | 17.1 | 2.0 |
| | Residential Property | 10.3 | 3.1 | 6.9 | 0.4 |
| | Workers' Compensation | 313.2 | 71.6 | 50.8 | 21.8 |
| | General Liability | 7.3 | 1.5 | 1.6 | 0.2 |
| | Group Life | 37.7 | 14.2 | 15.6 | 2.9 |
| Truck Bomb | **Total** | **11.8** | **5.5** | **8.8** | **3.0** |
| | Auto | 0.0 | 0.0 | 0.0 | 0.0 |
| | Commercial Property | 6.8 | 2.1 | 3.9 | 1.2 |
| | Residential Property | 0.0 | 0.0 | 0.0 | 0.0 |
| | Workers' Compensation | 3.5 | 2.8 | 3.9 | 1.5 |
| | General Liability | 1.2 | 0.4 | 0.7 | 0.2 |
| | Group Life | 0.3 | 0.2 | 0.3 | 0.1 |

The American Academy of Actuaries Terrorism Risk Insurance Subgroup appreciates the contribution of assistance from AIR Worldwide in the development of these estimates.

**STB Finance Docket No. 35517**

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**CF INDUSTRIES, INC. v. INDIANA & OHIO RAILWAY COMPANY, POINT COMFORT RAILRWAY COMPANY, and MICHIGAN SHORE RAILROAD, INC.**

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**REPLY COMMENTS**
**OF**
**NORFOLK SOUTHERN RAILWAY COMPANY**

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# EXHIBIT 6

Olin

# Wells Fargo Securities
## Industrial & Construction Conference

May 10, 2011

# Olin Representatives


**John E. Fischer**
Senior Vice President & Chief Financial Officer

**Larry P. Kromidas**
Assistant Treasurer & Director, Investor Relations
lpkromidas@olin.com
(314) 480 – 1452

# Company Overview

## Olin

| | Q1 2011 | FY 2010 |
|---|---|---|
| Revenue: | $ 436 | $ 1,586 |
| EBITDA: | $ 69 | $ 188 |
| Pretax Operating Inc.: | $ 220 | $ 77 |
| EPS (Diluted): | $ 1.66 | $ .81 |

## Chlor Alkali

Third Largest North American Producer of Chlorine and Caustic Soda

| | Q1 2011 | FY 2010 |
|---|---|---|
| Revenue: | $ 299 | $ 1,037 |
| Income: | $ 45 | $ 117 |

## Winchester

A Leading North American Producer of Small Caliber Ammunition

| | Q1 2011 | FY 2010 |
|---|---|---|
| Revenue: | $ 137 | $ 549 |
| Income: | $ 13 | $ 63 |

All financial data are for the quarter ending March 31, 2011 and the year ending December 31, 2010, and are presented in millions of U.S. dollars except for earnings per share. Additional information is available on Olin's website www.olin.com in the Investors section.

# Investment Rationale

- **Leading North American producer of Chlor-Alkali**
- Strategically positioned facilities
- Diverse end customer base
- **Favorable industry dynamics**
- Leading producer of industrial bleach with additional growth opportunities
- Pioneer and SunBelt acquisition synergies improved chlor-alkali price structure
- **Winchester's leading industry position**

# Acquisition of PolyOne's Interest in SunBelt

- On February 28, 2011, Olin purchased PolyOne's 50% interest in SunBelt for $132.3 million in cash plus the assumption of a PolyOne guarantee related to the SunBelt Partnership debt
- Olin and PolyOne agreed to a three-year earn out based on the performance of SunBelt
- The SunBelt 352,000 ton membrane plant located within Olin's McIntosh, AL facility, which has been operated by Olin since 1997, is now 100% owned by Olin
- Olin recorded a pretax gain of approximately $181 million and a deferred tax expense of $76 million as a result of an accounting remeasurement associated with the value of its original 50% interest in the SunBelt Partnership

# SunBelt Acquisition Benefits

- Olin expects the acquisition to be accretive to both EBITDA and earnings in 2011
- SunBelt currently has the lowest cash manufacturing costs in the Olin system
- SunBelt has a long-term contract for 250,000 tons of chlorine per year
- Expected annual synergies of $5-10 million associated with increased use of low cost capacity and increased sales of membrane grade caustic soda

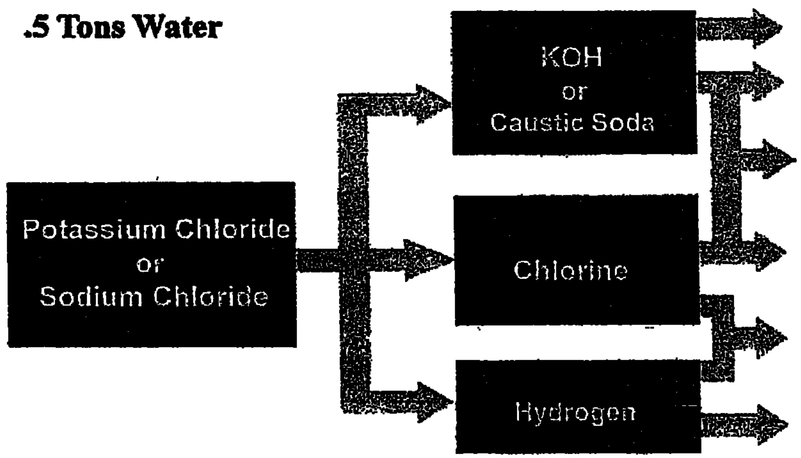
# Chlor Alkali Segment

## Chlor Alkali Manufacturing Process

**BRINE** + **ELECTROLYSIS** = **OUTPUTS**

1.8 Tons Salt &
.5 Tons Water

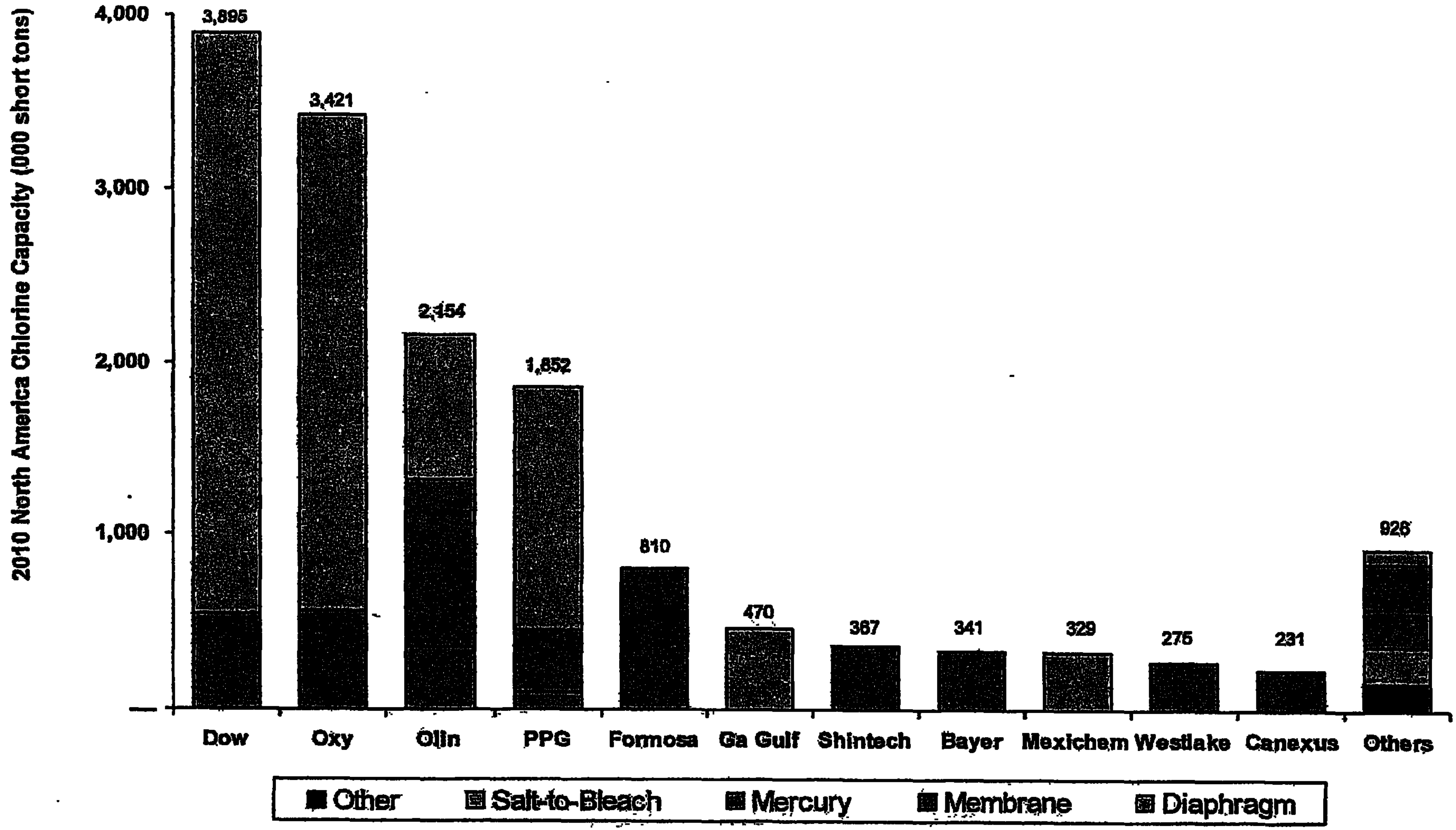
2.8 Megawatts Electricity




| Outputs | N. American Position | % 2010 Revenue |
|---|---|---|
| KOH – 1.59 Tons *(Potassium Hydroxide)* | #2 | 11% |
| Caustic Soda – 1.13 Tons *(Sodium Hydroxide)* | #3 | 42% |
| Bleach *(Sodium Hypochlorite)* | #1 Industrial | 10% |
| Chlorine – 1 Ton | #1 Merchant | 32% |
| HCl *(Hydrochloric Acid)* | #1 Burner Grade | 4% |
| Hydrogen Gas - 0.3 Tons | | 1% |

**ECU = Electrochemical Unit; a unit of measure reflecting the chlor alkali process outputs of 1 ton of chlorine, 1.13 tons of 100% caustic soda and 0.3 tons of hydrogen.**

# Olin is #3 Chlor-alkali Producer




Oxy includes OxyVinyls, PPG excludes Equa-Chlor and Olin includes 100% of SunBelt.

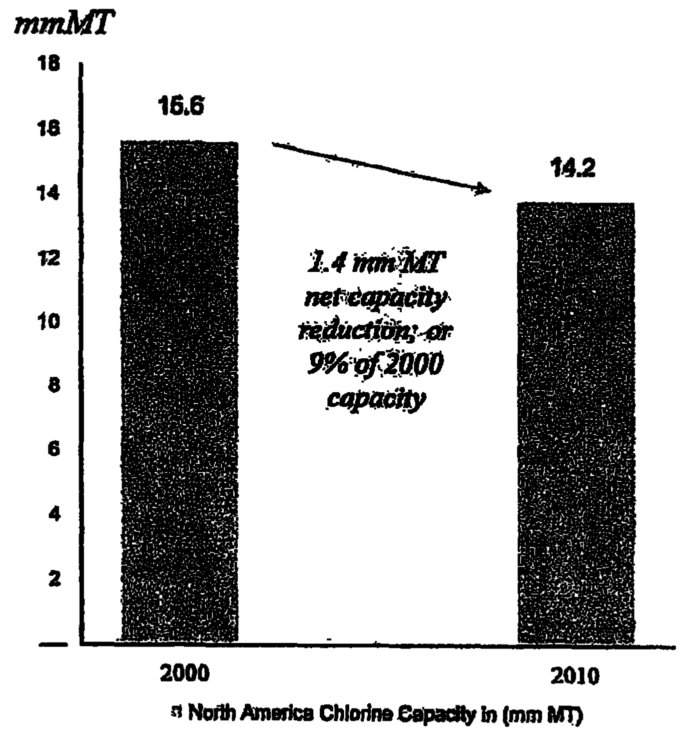
Source: CMAI/Olin – 2010 year-end figures

# Mercury Transition Plan

- The North American Chlor Alkali industry has been moving away from manufacturing chlorine and caustic soda using mercury cell technology due to customer product de-selection and threats of potential legislation
- Olin currently operates 2 mercury cell plants representing approximately 360,000 ECUs or 17% of our total capacity
- By the end of 2012, Olin expects to convert 200,000 ECUs of mercury cell technology to membrane technology and will shutdown the remaining 160,000 ECUs
- Estimated cost is $160 million over 2 years, aided by $41 million of low-cost Tennessee-sponsored tax-exempt debt

# Favorable Industry Dynamics

## Capacity Rationalization




Olin announced capacity reductions expected to be in place by 12/31/2012

Source: CMAI

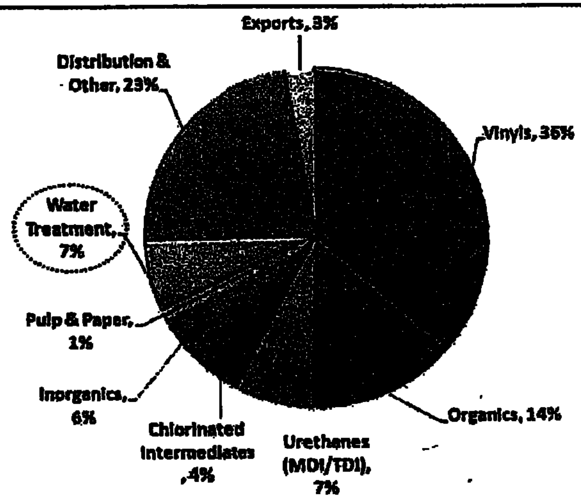
## Industry Consolidation

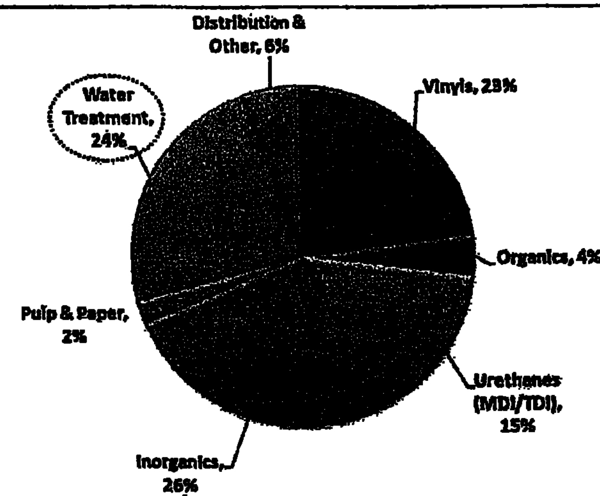
| Target | Acquisition Date | Position |
|---|---|---|
| Equa-Chlor | 2011 | • Acquired by PPG<br>• 70,000 Short Tons ECU Capacity |
| PolyOne | 2011 | • Olin acquired SunBelt interest<br>• 176,000 Short Tons ECU Capacity |
| Mexichem | 2010 | • Acquired by Cydsa/Iquisa<br>• 45,000 Short Tons ECU Capacity |
| Pioneer | 2007 | • Acquired by Olin<br>• 725,000 Short Tons ECU Capacity<br>• 4.7% of North American capacity |
| Vulcan | 2004 | • Acquired by OxyChem<br>• 859,000 Short Tons ECU Capacity<br>• 5.5% of North American capacity |

# Diverse Customer Base

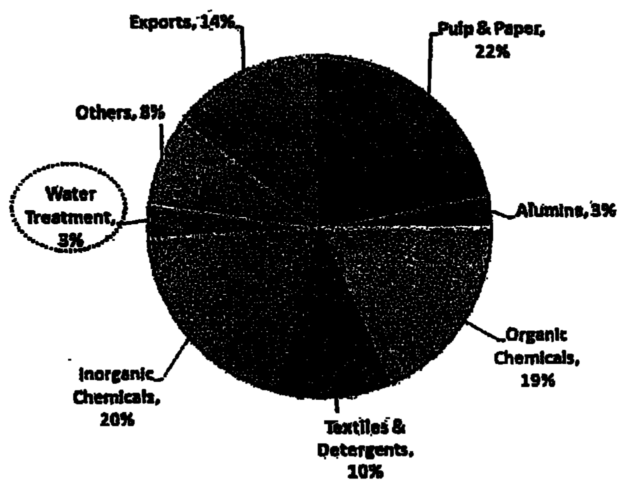
**North American Industry** | **Olin Corporation**

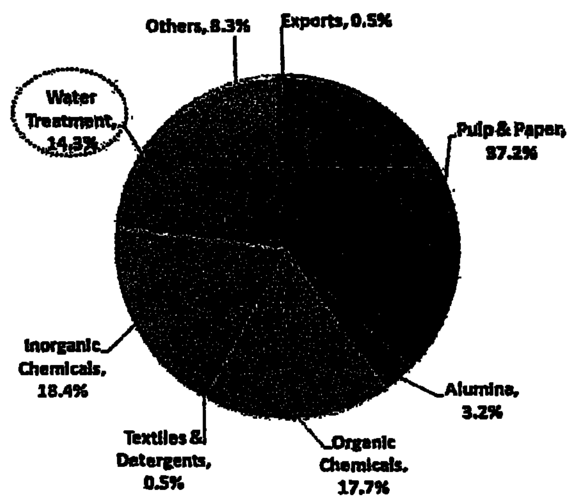
## Chlorine



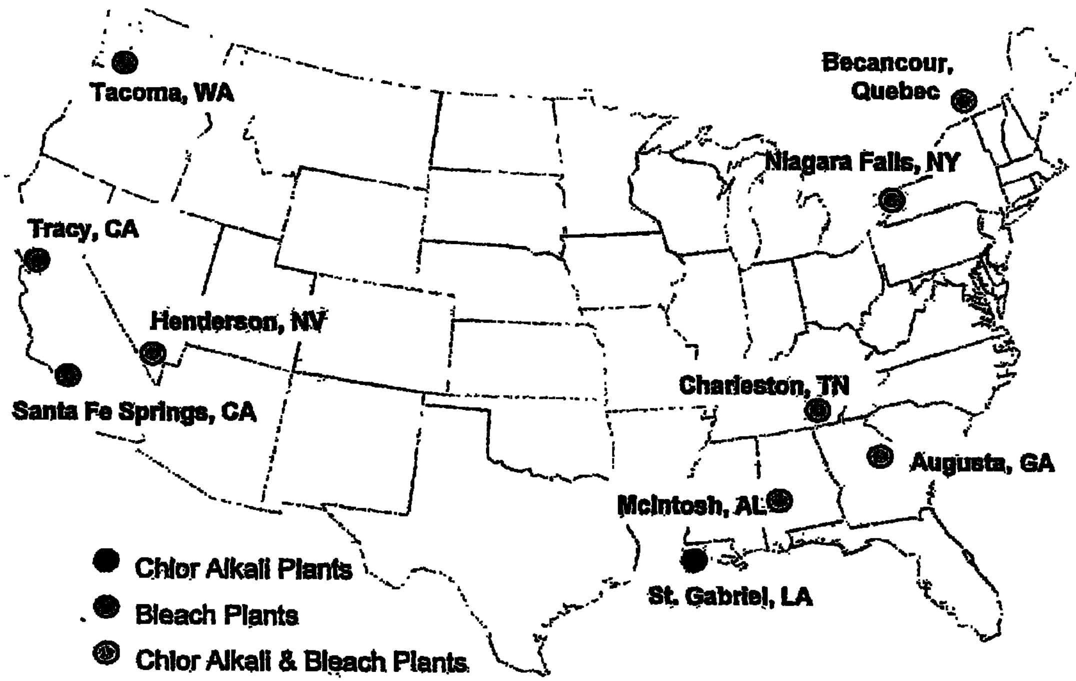

## Caustic Soda




Source: CMAI and Olin 2010 demand. Includes sales of SunBelt.
Chlorine: "Organics" includes: Propylene oxide, epichlorohydrin, MDI, TDI, polycarbonates. "Inorganics" includes: Titanium dioxide and bromine.
Caustic Soda: "Organics" includes: MDI, TDI, polycarbonates, synthetic glycerin, sodium formate, monosodium glutamate. "Inorganics" includes: titanium dioxide, sodium silicates, sodium cyanide.

# Olin's Geographic Advantage




| Location | Chlorine Capacity (000s Short Tons) |
|---|---|
| McIntosh, AL | 426 Diaphragm |
| McIntosh, AL - SunBelt | 352 Membrane |
| Becancour, Quebec | 252 Diaphragm<br>65 Membrane |
| Niagara Falls, NY | 300 Membrane |
| Charleston, TN (1) | 260 Mercury |
| St. Gabriel, LA | 246 Membrane |
| Henderson, NV | 153 Diaphragm |
| Augusta, GA (1) | 100 Mercury |
| Total | 2,154 |

- Access to regional customers including bleach and water treatment
- Access to alternative energy sources
  - Coal, hydroelectric, nuclear, natural gas

(1) Announced the conversion of 200,000 tons of mercury cell technology to membrane cell technology at the Charleston, TN facility and the closure of the mercury cell facility in Augusta, GA, both are expected to be completed by 12/31/12.

# Why Industrial Bleach?

- Olin is the leading North American bleach producer with 18% market share and current installed capacity to service 25% of the market with low-cost expansion opportunities
- Bleach utilizes both chlorine and caustic soda in an ECU ratio
- Bleach commands a premium price over an ECU
- Demand is not materially impacted by economic cycles
- Regional nature of the bleach business benefits Olin's geographic diversity, further enhanced by Olin's proprietary railcar technology to reach distant customers
- Low salt, high strength bleach investment will lower freight costs
- Bleach volumes accounted for almost 10% of total 2010 ECUs produced; these volumes are expected to grow to 15% to 20% in 2011

# Chlor-Alkali Outlook

- Q1 2011 ECU netbacks of $525 are up $85 over Q1 2010; we expect netbacks and volumes to continue to improve
- Positive price momentum from 2010 has continued in 2011:

| | Chlorine | Caustic Soda |
|---|---|---|
| 2010 Increases | $50 | $300 |
| January 2011 | | $ 40 |
| March 2011 | $60 | $ 60 |
| April 2011 | | $ 50 |

- Q1 2011 operating rates improved to 80% from 75% in Q1 2010 and are expected to increase in the second and third quarters of 2011
- Q1 EBIT is the highest level since the Q2 2009 and is expected to improve

# Winchester Segment

| Products | Retail | Distributors | Mass Merchants | Law Enforcement | Military | Industrial |
|---|---|---|---|---|---|---|
| | Hunters & Recreational Shooters | | | | | |
| Rifle | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Handgun | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Rimfire | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Shotshell | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Components | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

**Winchester Strategy**

- Leverage existing strengths
  - Seek new opportunities to leverage the legendary Winchester® brand name
  - Investments that maintain Winchester as the retail brand of choice, and lower costs
- Focus on product line growth
  - Continue to develop new product offerings
- Provide returns in excess of cost of capital

## Brands

# Favorable Industry Dynamics

| | |
|---|---|
| Commercial | • Economic environment leading to personal security concerns<br>• Fears of increased gun/ammunition control due to change in administration<br>• New gun and ammunition products<br>• Strong hunting activity in weak economy, driven by cost/benefit of hunting for food and increased discretionary time |
| Law Enforcement | • Significant new federal agency contracts and solid federal law enforcement funding<br>• Higher numbers of law enforcement officers and increase in federal agency hiring<br>• Increased firearms training requirements among state and local law enforcement agencies |
| Military | • Sustained high demand for small caliber ammunition due to wars in Iraq and Afghanistan<br>• Commitment to maintaining the "Second-Source Program" to mitigate the risk of a sole-source small caliber ammunition contract |

# Winchester

- Q1 2011 segment earnings of $12.5 million are $7 million lower than Q1 2010 earnings due to higher commodity costs
- Olin and the other two North American ammunition producers have announced price increases to be effective by June 1st
- Q1 2011 commercial backlog has declined by 50% from Q1 2010 levels reflecting the demand decline from the 2008 - 2010 surge levels; while Q1 2011 law enforcement and military backlog is comparable to Q1 2010 levels
- Winchester was recently awarded a 5 year contract to make 9mm rounds with a potential sales value of approximately $85 million
- We expect current year and future segment earnings to be in excess of earnings generated by the business prior to the most recent surge that began late 2008 and ended H2 2010.

# Centerfire Relocation

- The decision to relocate Winchester's centerfire operations, including 1,000 jobs, was made on November 3, 2010
- The controlled relocation process is expected to take up to 5 years to complete assuring that high quality product is available for our customers
- In 2011, we expect a $4 to $5 million negative pretax impact on earnings associated with the relocation project
- Annual operating costs are forecast to be reduced by $30 million once the move is complete
- The net project cost is estimated to be $80 million, of which approximately $50 million is related to capital expenditures
- $42 million of low-cost Mississippi-sponsored tax-exempt debt has been made available to the company

# Financial Highlights

- Strong Balance Sheet
  - The Q1 2011 cash balance of $380 million reflects the use of $132 million to acquire PolyOne's 50% interest in SunBelt and normal seasonal working capital needs
  - Pension plans remain fully funded with no contributions expected until at least 2013
  - 2011 CAPEX is forecast to be $235-$255 million reflecting the mercury conversion and Oxford relocation costs
- Profit Outlook
  - ECU pricing and volume trends are positive
  - Higher margin bleach business is growing
  - Acquisition of PolyOne's interest in SunBelt is expected to be accretive to EBITDA and earnings in 2011
  - Opportunity for highest level of EBITDA since Arch spin

# Forward-Looking Statements

This presentation contains estimates of future performance, which are forward-looking statements and actual results could differ materially from those anticipated in the forward-looking statements. Some of the factors that could cause actual results to differ are described in the business and outlook sections of Olin's Form 10-K for the year ended December 31, 2010 and in Olin's First Quarter 2011 Form 10-Q. These reports are filed with the U.S. Securities and Exchange Commission.

**STB Finance Docket No. 35517**

**CF INDUSTRIES, INC. v. INDIANA & OHIO RAILWAY COMPANY, POINT COMFORT RAILRWAY COMPANY, and MICHIGAN SHORE RAILROAD, INC.**

**REPLY COMMENTS**
**OF**
**NORFOLK SOUTHERN RAILWAY COMPANY**

# EXHIBIT 7

# Olin's CEO Discusses Q3 2011 Results - Earnings Call Transcript

**Executives**

John E. Fischer - Chief Financial Officer and Senior Vice President

Joseph D. Rupp - Chairman, Chief Executive Officer, President and Chairman of Executive Committee

John L. McIntosh - Senior Vice President of Operations

**Analysts**

Gregg A. Goodnight - UBS Investment Bank, Research Division

Frank J. Mitsch - Wells Fargo Securities, LLC, Research Division

Aleksey V. Yefremov - BofA Merrill Lynch, Research Division

Donald Carson - Susquehanna Financial Group, LLLP, Research Division

Herbert Hardt - Monness, Crespi, Hardt & Co., Inc., Research Division

Christopher W. Butler - Sidoti & Company, LLC

Edward H. Yang - Oppenheimer & Co. Inc., Research Division

Dmitry Silversteyn - Longbow Research LLC

Olin (OLN) Q3 2011 Earnings Call October 28, 2011 10:00 AM ET

**Operator**

Good morning, and welcome to Olin's Third Quarter 2011 Earnings Conference Call. [Operator Instructions] Please note this event is being recorded. I would now like to turn the conference over to Joseph Rupp, Chairman, President and CEO. Please go ahead.

**Joseph D. Rupp**

With me this morning are John Fischer, Senior Vice President and Chief Financial Officer; John McIntosh, Senior Vice President of Operations; and Larry Kromidas, our Assistant Treasurer and Director of Investor Relations.

Last night, we announced that net income in the third quarter of 2011 was $47.2 million or $0.58 per diluted share compared to $31.8 million or $0.40 per diluted share in the third quarter of 2010.

Sales in the third quarter of 2011 were $550 million compared to $432.8 million in the third quarter of 2010. Third quarter 2011 sales were the highest for Olin since the sale of the metals business that occurred in 2007.

The Chlor Alkali business's third quarter segment earnings of $76.7 million were the third highest quarterly earnings in history, and were realized despite an approximately $3 million negative impact due to a 10-day unplanned outage at our Charleston, Tennessee facility due to flooding caused by Tropical Storm Lee, and also due to weaker than expected chlorine demand that occurred late in the quarter. The Chlor Alkali business continued to experience positive pricing with ECU netbacks increasing sequentially for the eighth consecutive quarter. Also during the third quarter, bleach shipments were a record.

Winchester's third quarter results were in line with expectations but continue to be impacted by higher commodity metal costs. Also included in our third quarter results were pretax environmental recoveries of $1.5 million, a $3.7 million pretax gain on the sale of a former manufacturing site, and a pretax restructuring charge of $4.1 million associated with the Chlor Alkali mercury cell technology conversion in Charleston, Tennessee and the Winchester centerfire relocation project.

Fourth quarter 2011 net income is forecast to be in the $0.15 to $0.20 per diluted share range, reflecting normal seasonal weakness in both Chlor Alkali and Winchester and approximately $2.5 million restructuring charge primarily associated with the ongoing Winchester centerfire ammunition relocation project.

Chlor Alkali earnings were forecast to improve compared to the fourth quarter of 2010. Chlorine and caustic soda shipments are forecast to be lower than the fourth quarter 2010 levels but will be more than offset by higher selling prices. In the fourth quarter of 2011, Winchester results are forecast to be near breakeven and lower than the fourth quarter of 2010 as lower commercial volumes and higher commodity metal costs more than offset our improved pricing.

Now I'm going to discuss the segments, first with Chlor Alkali. The Chlor Alkali operating rate during the quarter was 85% and consistent with the outlook we provided during our second quarter earnings call. It declined as we moved through the quarter. Rate in July was 90%, and the rate in September was 81%. Expect this rate to decline further as we move through the fourth quarter. This reflects the normal seasonal slowdown in our bleach business and by many of our large chlorine customers. We've also seen a softening in demand from customers producing chlorine derivatives for export.

The third quarter operating rate included the impact of several planned and unplanned outages. The largest of these outages was the 10-day unplanned outage at Charleston, Tennessee facility. This was caused by approximately a 15-inch rain event associated with Tropical Storm Lee. We also had outages during the quarter at the Becancour, Canada plant, our Henderson, Nevada plant and our St. Gabriel, Louisiana plant. To take advantage of the weaker level of chlorine demand, we have scheduled additional maintenance and capital outages in the fourth quarter. Two of the outages are associated with electrical tie-ins of new capabilities.

At the McIntosh, Alabama facility, tie-ins will be done on the new high-pure bleach facility, which is approaching startup. And at the Charleston, Tennessee facility, initial tie-ins of the new membrane facility will be accomplished. Our operating rate during the fourth quarter is projected to be in the mid-70% range.

As a result of the weaker level of chlorine demand, we expect to see chlorine prices decline in the fourth quarter of 2011 when compared to the third quarter. Chlorine price declines in the fourth quarter of a year driven by weaker seasonal demand, are not unusual because of the weak outlook for the chlorine demand. As a consequence of lower operating rates, we expect caustic soda supply to remain tight. Therefore, we expect the $65 per ton caustic soda price increase announced in late August to be implemented consistent with our contract structure. We expect to realize some of this increase in the fourth quarter, and the largest amount will be realized in the first quarter of 2012.

Third quarter 2011 chlorine and caustic soda volumes declined 1% compared to the third quarter of 2010, and were 6% lower than the second quarter of 2011 levels. In addition to the outages, our chlorine production was negatively impacted by 2 large chlorine customers who began multi-month outages during the second half of the quarter.

On the positive side, we continue to experience growth in our bleach business. The third quarter 2011 volumes increased 7% compared to the third quarter of 2010. And during the first 3 quarters of 2011, bleach volumes have increased 19% compared to 2010 volumes. We expect our bleach business to continue to grow, driven by the investments we are making in high-pure bleach.

During the third quarter, we began construction of 2 additional high-pure bleach plants, one to be located at our Henderson, Nevada and the other at our Niagara Falls, New York chlor alkali plants. We expect these bleach plants, which represent capital spending commitments totaling approximately $40 million, to be operational by the fourth quarter of 2012. And as I said earlier, we expect our high-pure plant at McIntosh, Alabama to start production during the fourth quarter of this year.

The high-pure bleach process produces bleach that is twice the concentration of bleach produced by the processes we currently employ. It creates a higher value product that is less expensive to ship than either chlorine or conventional bleach.

Chlor Alkali has also experienced increased sales of hydrochloric acid during the third quarter. These shipments increased 6% compared to the third quarter of 2010 and 10% compared to the second quarter of 2011. We currently have the capability to produce this value-added product at 6 of our 7 chlor alkali manufacturing facilities, and we are in the process of modernizing and expanding that capability in Henderson, Nevada. In addition to being value-added products, both bleach and hydrochloric acid, because they are not classified as TH chemicals, are less expensive to ship than chlorine, and it's an important consideration for the business as our freight costs continue to be a major challenge.

Freight cost per ECU shipped in the third quarter of 2011 increased approximately 15% when compared to the third quarter of 2010. For the first 9 months of 2011, freight costs per ECU produced have increased 21% compared to the first 9 months of 2010. These cost increases continue to be driven by the cost of shipping chlorine by rail.

The Chlor Alkali business earned $76.7 million in the third quarter of 2011, which represents the third highest level of quarterly earnings ever and a significant improvement over the $44 million we earned in the third quarter of 2010. The year-over-year improvement reflects the combination of improved ECU pricing and the additional contribution from the acquisition of PolyOne's 50% ownership in Sunbelt.

The third quarter of 2011 ECU netback excluding Sunbelt was approximately $590 compared to approximately $465 in the third quarter of 2010. This represents the eighth consecutive quarter of improved ECU netbacks in our system. The acquisition of SunBelt contributed approximately $12 million of incremental profits in the third quarter of 2011. The Sunbelt ECU netback in the third quarter of 2011 was approximately $610.

Chlor Alkali fourth quarter 2011 segment earnings are expected to decline from the third quarter of 2011 but will exceed the fourth quarter 2010 earnings. ECU netbacks in the fourth quarter are forecast to decline slightly from the third quarter levels as chlorine price declines and less favorable customer mix more than offsets increases in caustic soda prices. Based on the lag we experienced in the realization of price increase, we expect that this ECU netback decline will be reversed in the first quarter of 2012.

In spite of the weaker forecast for the fourth quarter, the Chlor Alkali business in 2011 has experienced a significant improvement in earnings, above the levels that we achieved in 2009 and 2010. The business is also well positioned for further improvements in 2012. The business will begin 2012 in a strong pricing position and continued positive momentum on the caustic soda side. We also have the benefit of the 100% ownership of Sunbelt for the full year. We expect the bleach business to grow an additional 10% to 15%.

Now let me discuss Winchester. In early August, we announced that Winchester had been awarded a 5-year contract by the United States Army for the supply of 5.56-millimeter, 7.62-millimeter and 50-caliber ammunition. This contract, which is a follow-on to the second source contract awarded to General Dynamics in 2006, in which Winchester participated, the contract has the potential to generate total revenues of $300 million over the next 5 years. This is a significant accomplishment for our business, and it solidifies the outlook for Winchester's noncommercial sales for the next several years.

Winchester's third quarter 2011 commercial sales volumes continue to be stronger, and we would have expected it at the end of a surge period. This unexpected strength at commercial sales has been matched by continued strength in gun sales. Background checks, which are a strong indicator of future gun sales, remain well above the pre-surge levels.

The benefits from the better-than-expected levels of commercial sales have been more than offset by higher commodity metal cost. Third quarter 2011 purchase costs for copper have increased approximately 24% compared to the third quarter of 2010, and third quarter 2011 lead costs have increased approximately 16%. These levels of increase represent approximately $5 million in quarterly cost increases. On a year-to-date basis, in 2011, purchase copper costs have increased approximately 27% and lead cost approximately 14%, representing $16 million in annual cost increases. Metal costs have been a major challenge for the business in 2011.

During the third quarter, the initial relocation of production equipment from East Alton, Illinois to the new Oxford, Mississippi facility was successfully completed. There will be additional equipment relocations in the fourth quarter.

During 2011, the Winchester financial results are forecast to include $4 million to $5 million of costs associated with the overlap of support cost between East Alton, Illinois and Oxford, Mississippi facilities and other relocation-related costs. These costs, which negatively impacted the third quarter of 2011, will also have a negative impacted the fourth quarter of 2011 and into 2012. And as a reminder, we expect the relocation to Oxford, Mississippi to begin to generate meaningful cost savings in the second half of 2013, and we remain on target to realize the full $30 million of annual savings by 2016.

Winchester earned $13.1 million in the third quarter of 2011, which compares unfavorably to the third quarter of 2010 in which the earnings were $18.8 million. The decline reflects the negative impact, higher commodity metal cost and the additional cost associated with the centerfire relocation project, which more than offset favorable product pricing.

Fourth quarter 2011 Winchester earnings, which are expected to reflect normal seasonal weakness, are forecast to decline slightly from the fourth quarter 2010 levels. The combination of year-to-date Winchester earnings and fourth quarter outlook are projected to result in 2011 earnings that will be the third highest in the history of the business and more than double the average annual earnings in the 10 years prior to the 2009 peak year.

Strong earnings are consistent with our view, but after the completion of the surge, Winchester's earnings will be higher than prior to the start of the surge. With the confirmation of this view and with the longer-term benefits to be realized from the centerfire relocation project, we are optimistic about the future of Winchester and the contributions it will continue to make to Olin.

In spite of the weaker fourth quarter outlook, I remain optimistic about the prospects for the business. 2011 segment earnings in Chlor Alkali will likely more than double from 2010 levels, and Winchester's 2011 segment earnings continue to be well above historic levels. In addition, there's positive pricing momentum for caustic soda, and we're well positioned to continue the strong growth that we've experienced in the bleach business.

I'd like to turn the call over to John Fischer, who will review several financial matters with you. John?

**John E. Fischer**

Thanks, Joe. First, I'd like to discuss a few items on the income statement. Selling and administration expenses increased $6.5 million or 20% in the third quarter of 2011 compared to the third quarter of 2010. The year-over-year increase reflects the inclusion of approximately $3 million of Sunbelt selling and administration expenses as consolidated Olin expenses, higher salary and benefit cost, higher employee relocation expense and higher bad debt expense, partially offset by lower management incentive costs, which included mark-to-market adjustments that reduced stock-based compensation and lower legal and legal-related settlement costs.

The inclusion of the Sunbelt expenses of approximately $6 million have caused absolute year-over-year selling and administration expenses to be unfavorable on a year-to-date basis in 2011, and this will continue for the balance of the year.

Third quarter 2011 charges to income for environmental investigatory and remedial activities were $2.5 million, which included $1.5 million of recoveries from third parties for environmental costs incurred and expensed in prior periods. During the third quarter of 2010, there were $8.4 million of charges related to environmental, investigatory and remedial activities, which included $200,000 of recoveries for environmental costs incurred in expense from prior periods.

After giving consideration to the recoveries in both periods, year-over-year expense related to environmental remedial and investigatory activities decreased by $4.6 million. These charges related primarily to expected future investigatory and remedial activities associated with past manufacturing operations and former waste disposal sites.

We forecast that full year 2011 expenses for environmental, investigatory and remedial activities, prior to any recoveries, will increase as much as 25% from 2010 levels. We currently do not expect additional recoveries in 2011 of environmental costs incurred and expensed in prior periods.

On a total company basis, defined benefit pension plan income was $6 million in the third quarter of 2011 compared to $5.3 million in the third quarter of 2010. We are not required to make any cash contributions to our domestic defined benefit pension plan in 2011 and continue to believe the earliest we may be required to make any cash contributions to that plan is 2013. In 2011, we do expect to make a cash contribution to our Canadian defined benefit pension plan of less than $5 million. Under Canadian pension rules, service costs are required to be funded annually.

Defined contribution pension plan expense was $3.5 million in the third quarter of 2011 compared to $3.3 million in the third quarter of 2010. The vast majority of our employees now participate in the defined contribution pension plan. Our defined benefit pension plan is frozen to new entrants, all salaried, all non-union hourly and most union employees.

The third quarter 2011 effective tax rate was 32%. We continue to believe that full year effective tax rate will be in the 36% to 37% range with a fourth quarter rate similar to the third quarter.

During 2011, Olin will continue to benefit from the accelerated depreciation provided for in the Tax Relief, Unemployment Insurance Reauthorization and Job Creation Act of 2010, and we forecast a cash tax rate, excluding the taxes recorded as part of the remeasurement of Olin's 50% ownership interest in the Sunbelt partnership that took place in the first quarter, of approximately 23%.

Earlier, Joe mentioned the $4.1 million restructuring charge included in the third quarter 2011 results. This charge is associated with exiting the use of mercury cell technology in the Chlor Alkali manufacturing process by the end of 2012 and the ongoing relocation of our Winchester centerfire ammunition manufacturing operations from East Alton, Illinois to Oxford, Mississippi. Over the next 3 years, we anticipate that additional restructuring charges will be recognized associated with these actions.

During the fourth quarter of last year, an initial $34.2 million charge was recorded associated with the Winchester relocation, the Chlor Alkali Charleston, Tennessee mercury cell conversion and the Augusta, Georgia plant reconfiguration. Under the current accounting rules, which were changed several years ago, certain types of costs, including employee relocation, building demolition and certain other employee costs, are required to be expensed as incurred. As a result, we expect to incur approximately $8 million of additional restructuring charges associated with the Chlor Alkali projects between now and the end of 2012 and approximately $18 million of additional restructuring charges associated with the Winchester relocation between now and the end of 2016.

Finally, during the third quarter of 2011, we recorded a pretax gain of $3.7 million on the sale of a former manufacturing site.

Now turning to the balance sheet. Cash and cash equivalents at September 30, 2011, including the restricted cash associated with the Go Zone and Recovery Zone financings that were completed in 2010 and are classified as a long-term asset on the balance sheet, totaled $389.9 million.

At the end of the third quarter of 2011, $36 million of the $153 million of Go Zone and Recovery Zone bonds issued were undrawn. We expect that this undrawn balance will be fully drawn by the end of 2011. We also expect that at the end of 2011, there will be approximately $40 million of cash that will remain restricted and will be available to fund 2012 capital spending.

During the first 9 months of 2011, there's been approximately $71 million of working capital growth. This reflects the normal seasonal pattern in both businesses amplified by the improved volumes of bleach sales in Chlor Alkali and higher commodity metal prices in Winchester. Consistent with the normal annual pattern, we expect the majority of this working capital growth to be liquidated by the end of the year.

In December 2011, we have $75 million of bonds that were issued in 2001 that matured. It's currently our intention to redeem these bonds using our cash. Also in December, $12.2 million of the Sunbelt notes will be repaid. The SunBelt notes require $12.2 million of repayments annually through the end of 2017.

Full year 2011 capital spending is projected to be approximately $255 million compared to $85.3 million in 2010. Approximately 65% of this spending is related to the Charleston, Tennessee mercury cell conversion project and the Winchester relocation project. Year-to-date, these projects have accounted for approximately 57% of total capital spending.

The capital spending for the Winchester relocation project will be partially financed by approximately $31 million of grants provided by the state of Mississippi and other local governments. We expect depreciation expense to be in the $100 million range for 2011.

During the third quarter, we initiated actions under the $5 million share repurchase program that was approved in July. In the third quarter, approximately 125,000 shares were repurchased at a cost of approximately $2.2 million. Yesterday, Olin's Board of Directors declared a dividend of $0.20 on each share of Olin common stock. The dividend is payable on December 9, 2011, to shareholders of record at the close of business on November 10, 2011. This is the 340th consecutive quarterly dividend to be paid by the company.

Before we conclude, let me remind you that throughout this presentation, we have made statements regarding our estimates of future performance. Clearly, these are forward-looking statements and then results could differ materially from those projected. Some of the factors that could cause actual results to differ are described, without limitations, in the risk factor sections of our most recent Form 10-K and in our third quarter earnings release. A copy of today's transcript will be available this afternoon on our website in the Investors section under Calendar of Events. The earnings press release and other financial data and information are available under Press Releases.

Now operator, we're now ready to take questions.

**Question-and-Answer Session**

**Operator**

[Operator Instructions] The first question comes from Frank Mitsch of Wells Fargo.

**Frank J. Mitsch - Wells Fargo Securities, LLC, Research Division**

I wanted to try and size the Chlor Alkali outages that you're planning in the fourth quarter and also talk a little bit about operating rates. In the third quarter, your operating rates, on average, were 85%, which was in line with the industry even though you had planned and unplanned outages, et cetera. But obviously, business started to slow down, and you're forecasting mid-70% in the fourth quarter. Do you expect the industry to also be dropping that far down? Or is it mainly related to some of the outages that you -- or the unplanned downtime or planned downtime that you have?

**John L. McIntosh**

Frank, I expect the industry to be in roughly the same operating rate range in the fourth quarter. We've seen pretty significant falloff in demand for chlorine, chlorine derivatives, and I expect that to translate across the industry. I would add that if you look at our outages, total outages in the fourth quarter, it represents, in our system, about 5% of capacity. Our expected operating rate for the fourth quarter, you know, mid-70s, is about the midrange of our fourth quarter operating rate for the last 3 years. So what we're seeing is not out of the ordinary for a fourth quarter for Olin's system.

**Frank J. Mitsch - Wells Fargo Securities, LLC, Research Division**

All right. Terrific. And John you mentioned that -- or the comment was that the 2 large chlorine customers, multi-month outages. When do you anticipate that they'll be back up?

**John L. McIntosh**

We have one customer that shut down in the end of July that should be starting up or is scheduled to start up next week. Another customer that started down -- shut down the end of August, that's supposed to start up the end of November.

**Frank J. Mitsch - Wells Fargo Securities, LLC, Research Division**

All right. Great. And then --

**Joseph D. Rupp**

One of those customers, Frank -- one of the customers -- length of their shutdown is combined with a capital investment that they're doing. That's why it's pretty lengthy.

**John L. McIntosh**

That's why it's a little bit long.

**Frank J. Mitsch - Wells Fargo Securities, LLC, Research Division**

All right. Terrific. Terrific. And just if you guys could offer a comment with respect to the share buyback, $2.2 million in the third quarter. Any comments on the pace that you're planning to execute on that $5 million share buyback?

**John E. Fischer**

I think, Frank, we intend to be an opportunistic buyer of Olin shares and with a goal to offset dilution over time. And that's what we're targeting.

**Operator**

The next question comes from Edward Yang of Oppenheimer.

**Edward H. Yang - Oppenheimer & Co. Inc., Research Division**

Joe mentioned that you still expect the Chlor Alkali business to improve in 2012 year-over-year. So how much can we extrapolate the operating rate that you expect in the fourth quarter in the mid-70s out into 2012? What would your expectation be, for example, for first quarter of next year?

**John L. McIntosh**

We have historically seen operating rates from fourth quarter of one year to first quarter of another -- of a subsequent year increase in the 5% to 8% range. And for us, peak quarters from an operating rate standpoint tend to be the second and third quarter, when we have the full benefit of all the seasonal business that we serve, especially our bleach business.

**Edward H. Yang - Oppenheimer & Co. Inc., Research Division**

And John, accounting for that seasonality then, would you expect your operating rate to be down year-over-year in the second quarter of next year versus today under -- given your current assumptions?

**John E. Fischer**

No.

**Edward H. Yang - Oppenheimer & Co. Inc., Research Division**

Okay. And you mentioned that the mid-70s range that you see for the fourth quarter is kind of the average of what you've seen in the last 3 years, but that included a pretty severe recession. I would think that an operating rate this low -- that would sorry, go ahead.

**Joseph D. Rupp**

If you take the recession year out and just take the last 3 years -- and we're right in the midpoint of that to be quite frank about it. Forget '08, when everything collapsed. That was when we had the 67% operating rate.

**John E. Fischer**

'07, '09 and '10 averaged out to 75%.

**Joseph D. Rupp**

75%.

**Edward H. Yang - Oppenheimer & Co. Inc., Research Division**

Okay. I thought that fourth quarter -- kind of a typically year would be more in the 80s or the mid-80s or so. But this mid-70s, you believe is -- okay. All right. So it's in the midpoint then. Okay. Got you. Are there any cost-cutting actions that you could take as you've this drop-off in chlorine demand?

**John L. McIntosh**

Well, for the kind of just one quarter demand that we see, it's pretty hard to make major changes on the cost side. What we do do is it does afford us the opportunity to take opportunistic shutdowns in a period of time in which we can do that in the most cost-effective manner, and it also allows us to manage the logistics side of our business in a manner in which we can limit out-of-order purchase shipments and take full advantage of our multi-plant network and really lower the supply chain cost that we have.

**Edward H. Yang - Oppenheimer & Co. Inc., Research Division**

Maybe following up on that line of thinking then, John. When you made the SunBelt acquisition, I believe it was -- the final payment was going to be contingent on earn-outs, but that's probably one of your most profitable plants. So would the demand -- the diminished demand you're seeing on the chlorine side, does that -- would you see any benefit from that from, let's say, paying out less of the Sunbelt earn-outs or reversing any accruals that you might have had for that?

**John E. Fischer**

We haven't really talked about the amount of the earn-out. It is a 3-year earn-out, and I think we will run the business in the manner that generates the best financial return for Olin's shareholders.

**Operator**

The next question comes from Christopher Butler of Sidoti & Company.

**Christopher W. Butler - Sidoti & Company, LLC**

Just wanted to shift gears over to Winchester here a bit. Now that we have some visibility into the full year of kind of 2009 post peak demand Winchester, how do guts see this working out here over the next year, the next 2 years? Is this going to be a slow decline back to normal? Have we kind of found a stabilization here above where we expected? What do you think?

**Joseph D. Rupp**

Chris, we think we're troughed out is where we are. We're -- we'll stay stable, with the ability to increase as time marches on.

**Christopher W. Butler - Sidoti & Company, LLC**

And the pullout from Iraq is -- and things of that nature not a concern to you at this point?

**Joseph D. Rupp**

Not in the immediate future. Longer term, it will be, but not as we look forward here in the next year or 2.

**John E. Fischer**

Chris, one point I think we should make about the recent second source award. We were a participant in the prior second source award, but we only performed between 40% and 50% of that total contract value. The new contract provides us the opportunity to perform 100%, which if volumes are equal, that would double that component of our sales. Now we're not thinking that, because we do believe there'll be budget reductions and stuff and as we move through time. So that's actually an opportunity for us to actually have better military sales than we've had historically. And at worst, if the volume is purchased and the new second source are only half of what they were in the prior second source, we'd still be even. So I think that's really good news for us in terms of the business base.

**Christopher W. Butler - Sidoti & Company, LLC**

And looking at the profitability side of the equation, could you talk to the pricing environment and your ability to offset some of these higher metal costs that you've been dealing with?

**Joseph D. Rupp**

We actually have pricing action. It took effect the 1st of July, Chris. It's working its way in, and you know how we buy our metal. We're -- our -- we're hedged out a couple of quarters, and so that's all going to work its way through the system. So we would anticipate that as we get out further, that our pricing will start to offset the commodity cost increase.

**Christopher W. Butler - Sidoti & Company, LLC**

And just looking at the balance sheet really quick, you had mentioned that working capital normally increases during the year and falls by the end. But if we're look at working capital sequentially here into the third quarter, it looks like you reduced it when normally, it's fairly flat. With demand weakening in Chlor Alkali at the very end of the quarter, I'm surprised that there wasn't an uptick on inventory as a result. Can -- have you done anything differently there?

**John E. Fischer**

The bigger driver of the third quarter and most of the working capital growth during the year is Winchester. And we saw a very robust third quarter sales for Winchester, and that's really the bigger driver than the Chlor Alkali piece.

**Operator**

The next question comes from Herb Hardt of Monness.

**Herbert Hardt - Monness, Crespi, Hardt & Co., Inc., Research Division**

Question is potential for overseas ammunition contracts. Is there anything in the wings on that?

**Joseph D. Rupp**

Not much, Herb. There's periodically are opportunities there but not many. Most of our sales are pretty much domestic.

**Operator**

The next question comes from Don Carson of Susquehanna.

**Donald Carson - Susquehanna Financial Group, LLLP, Research Division**

Question on ECU pricing. You were $590 in the quarter. That was only up $7. Just wondering what the dynamics were of how much of the cost of increase rolled through and what the offset was on chlorine. And just remind me, your bleach realizations are not in that ECU number. Is that correct?

**John E. Fischer**

I think, Don, the quarter-over-quarter increase was $40. We were at $550, and now, we're at $590. And you're right. The bleach realizations are not in that number.

**Donald Carson - Susquehanna Financial Group, LLLP, Research Division**

Okay. And what's was the dynamics? How much was chlorine down versus caustic up?

**John E. Fischer**

Chlorine was roughly flat. It was all cost caustic up.

**Joseph D. Rupp**

Offset by higher -- then you get the higher transportation cost, as you know, Don.

**Donald Carson - Susquehanna Financial Group, LLLP, Research Division**

Now as we look into the fourth quarter, you said you're hoping to get a portion of that 65%, maybe 20% to 25%, but I assume that chlorine is going to offset much of that. So are you looking at relatively flat ECUs here in Q4?

**Joseph D. Rupp**

That's correct.

**Donald Carson - Susquehanna Financial Group, LLLP, Research Division**

Okay. And then as you go forward with your bleach expansions, ultimately, just say if you look out a year, what proportion of your overall ECUs will be going into bleach? And is that -- are you still able to realize about $100, $150 ECU premium on bleach?

**John E. Fischer**

In 2011, Don, a little over 10% of our total capacity will be sold as bleach. And to date, we have continued to realize at the high end of the $100 to $200 per ton premium that we have talked about.

**John L. McIntosh**

Don, when you look at the addition of the high-pure bleach capacity that Joe alluded to in his remarks, the -- which will occur within the next 2 years, that will basically add 1/3 of our current system capacity. So we will have the opportunity to grow that 10% correspondingly.

**Joseph D. Rupp**

We stated that our -- we're trying to get it to 15% to 20%. That's where we're trying to get to.

**Donald Carson - Susquehanna Financial Group, LLLP, Research Division**

And just a question on ECU pricing as we get into 2012. Obviously, caustic's being held up here, because there's not much of an outlet for chlorine, but how would you see that unfolding? And I'm just wondering how much -- clearly, end market demands weakened for chlorine derivatives, not just vinyls, but it's a sign as well. But I'm wondering what impact this new capacity we've seen this year for Chlor Alkali has also contributed to the weakness in operating rates.

**Joseph D. Rupp**

We don't think it's contributing at this point, the new capacity. And what we think is going to happen is that caustic's going to be tight, and it's going to be tight into the first quarter. And then I think everybody's crystal ball will be what happens to the economy. Normally, what would start to happen is chlorine starts to pick up in the late February, early March period. It will for us, because we'll be heading into the bleach season.

**Donald Carson - Susquehanna Financial Group, LLLP, Research Division**

Okay. And what's your outlook for freight rates next year, Joe? I know that's a subject of...

**Joseph D. Rupp**

I think they're going to continue to go up.

**Operator**

The next question comes from Alex Yefremov of BofA Merrill Lynch.

**Aleksey V. Yefremov - BofA Merrill Lynch, Research Division**

I just wanted to ask a question on ECU, your expectation of higher ECU realizations in Q1 2012. Does this assumption include improvement or flattening in chlorine prices or continued decreases there?

**John L. McIntosh**

It assumes chlorine prices will stay relatively where they are. Just to comment on caustic, if you look at 2011 and you add up all the price increases in the year, there were a total of $240 of price increases announced. If you look at the benchmark indexes, through the third quarter of this year, only $100 of that $240 has been realized in the marketplace. We feel like there's still a lot of room to go, and we've actually seen improvement in caustic pricing in the fourth quarter, so far in the fourth quarter. So we believe, as has been said in earlier comments, that we have opportunity for caustic pricing to continue into the first part of 2012.

**Aleksey V. Yefremov - BofA Merrill Lynch, Research Division**

Okay. And a question on the high-strength bleach facility. Could you help us size potential impact on sales and EBIT after the startup sort of based on a steady state run rate in 2012?

**John E. Fischer**

John just said that we are expanding our bleach capacity by roughly 1/3, and we said today it's about 200,000 tons. So it would be roughly 60,000 tons, and we've set the margin. Favorable margin impact is between $100 and $200 per ton. I will caution you that that is a seasonal business, where about 70% of what we sell, we sell in quarters 2 and 3.

**Aleksey V. Yefremov - BofA Merrill Lynch, Research Division**

Sort of, I guess, a follow-up to that. Do you think as you ramp your bleach volumes, your seasonality would increase, and that's part of what's happening this year already, because your bleach volumes are higher?

**John E. Fischer**

That's absolutely one of the factors that's contributing to the move from Q3 to Q4. I would also add that we have seen a much more normal move in Winchester seasonally than we've seen in the last couple of years, because the surge sort of overcame some of that.

**Aleksey V. Yefremov - BofA Merrill Lynch, Research Division**

I see. Do you see any other end markets where sort of there's more pronounced seasonality this year I guess other than maybe -- within chlorine derivatives, which markets are doing worse than others?

**John L. McIntosh**

I don't know that you can attribute it as much to seasonality as just kind of attribute it to worldwide demand patterns. But the derivative product, the derivative exports, chlorine-based derivative exports have really dropped off the end of the third quarter and at least, so far, in the fourth quarter. And I don't think that's seasonality as much as it's just worldwide economic -- worldwide demand driven by what the economies are doing.

**Operator**

The next question comes from Dmitry Silversteyn of Longbow Research.

**Dmitry Silversteyn - Longbow Research LLC**

I'm still struggling a little bit with fourth quarter guidance. I understand the seasonal decline from the third quarter to the fourth quarter from point of view of bleach and lower chlorine demand and volumes. But it you just compare it to the third -- to the fourth quarter of 2010, I mean, you got more than -- $50 more in ECU netback if not greater. Volumes, actually, including SunBelt, are going to be up. So I'm just trying to understand -- how do I get my number down below $50 million in profits, I guess, is my question.

**John E. Fischer**

I think, Dmitry, if you look at last year's fourth quarter and you look at the segment results and you look at the corporate and other line, there's about a $10 million to $12 million year-over-year change. Last year's fourth quarter essentially included no environmental expenses because of the absence of discrete events and some recoveries. There were some good news in terms of a reimbursement from the government on retiree medical that went with the healthcare law, and there were some adjustments to asset retirement obligations. They ran through as a result of the restructuring charge. Those 3 alone, on a year-over-year basis, are -- 2011 is $10 million higher than it was in 2010, and I think that's probably the piece that you're missing.

**Dmitry Silversteyn - Longbow Research LLC**

Okay. So basically, you're talking about a higher corporate expense then. And your Chlor Alkali production or profitably is going to be -- I don't want to say 50% higher but significantly higher than it was in December of 2010 quarter, right?

**John E. Fischer**

That's correct.

**Dmitry Silversteyn - Longbow Research LLC**

Okay. All right. So that explains or helps to explain that a little bit. Secondly, on your tax rate, I mean it's been fluctuating a little bit here. So what should we think about not just for the fourth quarter but as we look longer term at your tax rate?

**John E. Fischer**

I think after adjustments, it's a 36% to 37% rate, which is what we've set for the full year 2011.

**Dmitry Silversteyn - Longbow Research LLC**

Okay. So -- oh, even for the full year 2011, it'll be that high?

**John E. Fischer**

Yes. I think it was quite a bit higher than that in Q1.

**Dmitry Silversteyn - Longbow Research LLC**

Right. It was 35% in Q1, and it was 32% in Q3. So for us to get to 37% or 36%, we have to assume almost a 40% Q4 tax rate. Is that the right way to think about that?

**John E. Fischer**

No. I think if you go back and look at Q1 and Q2, I think we're above that 36% to 37% rate. To answer your question on future guidance, I would guide you to a 36% to 37% rate on a consistent basis going forward.

**Operator**

The next question comes from Gregg Goodnight of UBS.

**Gregg A. Goodnight - UBS Investment Bank, Research Division**

You mentioned that you're going to take some opportunistic shutdowns and do some tie-ins in the fourth quarter related to projects and others. My question is, is that work going to be expensed or capitalized? If it's going to be expensed, how much of an incremental cost of that is in the fourth quarter?

**John L. McIntosh**

There really isn't a significant incremental expense cost associated with it. The opportunistic stuff we're doing is really capital related.

**Gregg A. Goodnight - UBS Investment Bank, Research Division**

Okay. So it's -- it doesn't have an EPS impact then in the fourth quarter.

**John L. McIntosh**

Yes, sir.

**Gregg A. Goodnight - UBS Investment Bank, Research Division**

Okay. The second question I had was the -- any -- are there going to be any other environmental expenses or unusual charges in the fourth quarter that's included in your guidance for your corporate area?

**John E. Fischer**

I wouldn't call it unusual. There is variability in environmental expenses. We do not see any recoveries in Q4 of '11, whereas in Q4 of '10, we did, and so there's a year-over-year unfavorable comparison. But I think if you look at environmental across 2011, as we said, it'd be about 25% higher than 2010 but well within historic range.

**Gregg A. Goodnight - UBS Investment Bank, Research Division**

Okay. And the last question I have is your guidance that you're giving is on a GAAP basis, I assume. It's not an adjusted basis.

**John E. Fischer**

That's correct.

**Gregg A. Goodnight - UBS Investment Bank, Research Division**

Okay. Oh, I'm sorry. I do have one more question. Energy costs, could you typify your energy cost in third quarter versus second and then fourth quarter versus third? Is it fairly flat? Or are we seeing any trends at all?

**John L. McIntosh**

We typically -- energy costs -- although the difference isn't significant, energy costs, during the peak times of the year, which are typically second quarter, third quarter, do tend to be a little bit higher. A lot of that's driven by operating rate, but it's also driven by just the fact that overall demand is higher in those quarters. And we buy a little bit higher price to mix of electricity because of that, but it's not a significant delta from those quarter-to-quarter.

**Operator**

This concludes our question-and-answer session. I would like to turn the conference back over to Joseph Rupp for any closing remarks.

**Joseph D. Rupp**

I'd like to thank you for joining us today as we've reported our third quarter results, and we look forward to speaking with you in January of 2012 when we report on the results of our full year and our fourth quarter. Thank you.

**Operator**

The conference has now concluded. Thank you for attending today's presentation. You may now disconnect.

**STB Finance Docket No. 35517**

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**CF INDUSTRIES, INC. v. INDIANA & OHIO RAILWAY COMPANY, POINT COMFORT RAILRWAY COMPANY, and MICHIGAN SHORE RAILROAD, INC.**

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**REPLY COMMENTS**
**OF**
**NORFOLK SOUTHERN RAILWAY COMPANY**

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# EXHIBIT 8

# Rail Transportation of Toxic Inhalation Hazards: Policy Responses to the Safety and Security Externality

HARVARD Kennedy School
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Science, Technology, and Public Policy Program
Harvard Kennedy School
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# Rail Transportation of Toxic Inhalation Hazards

## Policy Responses to the Safety and Security Externality


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## Abstract

Toxic inhalation hazard (TIH) chemicals such as chlorine gas and anhydrous ammonia are among the most dangerous of hazardous materials. Rail transportation of TIH creates risk that is not adequately reflected in the costs, creating a TIH safety and security externality. This paper describes and evaluates policy alternatives that might effectively mitigate the dangers of TIH transportation by rail. After describing the nature of TIH risk and defining the TIH externality, general policy approaches to externalities from other arenas are examined. Potential risk reduction strategies and approaches for each segment of the supply chain are reviewed. The paper concludes by summarizing policy options and assessing some of the most promising means to reduce the risks of transportation of toxic inhalation hazards. Four policy approaches are recommended: internalizing external costs through creation of a fund for liability and claims, improving supply chain operations, enhancing emergency response and focusing regulatory authority. It is further suggested that the Department of Transportation convene a discussion among stakeholder representatives to evaluate policy alternatives.

## I. Introduction

Hazardous materials — industrial materials that are flammable, corrosive, toxic, explosive, or infectious — play a vital role in the U.S. economy. They are used by industries from farming and mining to manufacturing and pharmaceuticals, in the form of fertilizers, raw materials, fuels, and other essential inputs. Of all hazardous materials, toxic inhalation hazards (TIH) may be among the most dangerous.[1] Chlorine gas and anhydrous ammonia are the most common TIH chemicals; others include sulfur dioxide, ethylene oxide, and hydrogen fluoride, and a variety of other products that are important manufacturing inputs.[2]

After the terrorist attacks of September 11, 2001, the security of hazardous materials became increasingly salient in public concern and political debate. Release of toxic inhalation hazards, whether the result of attack or accident, could result in devastating consequences. Many hazardous chemicals are transported over long distances by rail, during which they are particularly vulnerable.[3]

Safety from accidents as well as security against attack are of concern. Toxic inhalation hazards were involved in a number of deadly rail accidents in the early part of this decade. They could have been far worse: all of the TIH accidents we describe in this paper occurred at night in areas of relatively sparse population, limiting the number of people exposed to the effects of the chemicals. A daylight TIH release in a densely populated area could have catastrophic consequences.

Movement of TIH materials through the supply chain creates risk for shippers, rail carriers, and the general public that is not quantified and is not adequately reflected in the costs, leaving a significant portion of the risk as an externality. Our focus, therefore, is on the TIH safety and security externality, that is, the consequences associated both with

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[1] Toxic inhalation hazards are also sometimes called poison inhalation hazards (PIH).

[2] "Six toxic-by-inhalation (TIH) chemicals (ammonia, chlorine, SO2, hydrogen fluoride, fuming nitric acid and sulfuric acid) account for more than 90% of the total TIH transportation related risk. Chlorine and ammonia account for 70% and 84 % of the transported TIH material." Mark Hartong, Rajni Goel, and Duminda Wijesekera, "A Risk Assessment Framework for TIH Train Routing," <volgenau.gmu.edu/~klaskey/OR680/MSSEORProjectsSpring08/RR_Group_09MAY2008/CIP_TIH_Submitted.pdf>, citing D.F. Brown; W.E. Dunn; and A.J. Policastro, "A National Risk Assessment for Selected Hazardous Materials in Transportation ANL/DIS-01-1," Decision and Information Sciences Division (Argonne National Laboratory), U.S. Department of Energy, January 2001.

[3] The United States has over 140,000 miles of freight rail. Several hundred thousand workers handle over 1.2 million hazardous materials movements daily.

accidents and with deliberately perpetrated attacks. Improving "safety" means reducing the accident risk; improving "security" means reducing the terrorist risk. Accidents and deliberate attacks may result in similar consequences. Therefore many safety regulations and policies will also mitigate, to some degree, the consequences of a security breach. The domains of safety and security overlap with respect both to mitigation and to consequence.

This study focuses on potential means of reducing the risk of TIH rail transportation by developing a better understanding of the safety and security externality and proposing a more comprehensive approach to the way that TIH materials are handled. The risk mitigation actions of individual stakeholders, while positive, may not be enough. A focus on incorporating the safety and security externality into the entire TIH supply chain would allow the participants in that supply chain to assess risks more effectively and to make better plans for the safe transport, storage, and delivery of TIH.

***What is the TIH Risk? Framing the Problem***

TIH chemicals are among the most dangerous hazardous materials because they are very toxic and they can spread easily in the air if released. Nonetheless, TIH chemicals are economically essential. Over $660 billion worth of hazardous materials were transported in the United States in 2002, the latest year for which comprehensive data are available, with each shipment moving an average of 136 miles.[4] Without the movement of these hazardous materials, gas stations would close, crop yields would diminish, potable water prices would rise, and many manufacturing activities would come to a halt.

We focus in this paper on two of the most extensively used TIH products, chlorine and anhydrous ammonia. Chlorine gas is used for purifying potable and waste water at treatment plants throughout the country and is also used as a chemical intermediary in various manufacturing processes, for products ranging from PVC pipes to shampoo.[5] Anhydrous ammonia is the nation's dominant commercial fertilizer and is applied extensively throughout the country's main agricultural regions, particularly the Midwest farm states.

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[4] U.S. Department of Transportation (DOT), Bureau of Transportation Statistics, "U.S. Hazardous Materials Shipments by Transportation Mode, 2002," <www.bts.gov/publications/national_transportation_statistics/html/table_01_56.html>.

[5] American Chemistry Council, "The Chlorine Tree," <www.chlorinetree.org>. But see Global Security Newswire, "Clorox to Halt Use of Chlorine at Bleach Production Sites," November 2, 2009, <gsn.nti.org/gsn/nw_20091102_6428.php>.

Most TIH chemicals are shipped from production locations to usage sites (although some are produced, stored, and used at a single site). Rail is generally preferred for long-distance transportation, since one rail tank car carries as much as four trucks. In 2007, almost two-thirds (64 percent) of TIH moved by rail, amounting to 105,000 rail-car shipments (TIH materials represent only a small portion of total hazardous materials transported by rail).[6] Rail transportation of TIH is generally believed to be safer than truck transportation, because a smaller number of shipments move along a fixed, dedicated network.

TIH rail transportation is not without risk. Deadly railway accidents involving TIH in Minot, North Dakota, in 2002, in Macdona, Texas, in 2004, and in Graniteville, South Carolina, in 2005 resulted in the evacuation of thousands of people, forced over 800 people to seek medical attention; and caused the deaths of 13 people.[7] The economic costs were staggering; the costs of the Graniteville accident were estimated at $126 million.[8] These accidents took place when relatively few people were exposed; a terrorist attack on TIH tank cars could have far worse results. One worst-case estimate predicted up to 100,000 deaths should a chlorine gas tank car be attacked and breached on the rail line that passes the Capitol Mall in Washington, D.C. during a major outdoor public event.[9] Although there have been no incidents of terrorist use of TIH in the United States, in Iraq in 2007 there were several attacks on chlorine containers carried by trucks.[10]

Rail transportation providers, aware of the danger, have undertaken risk-mitigation activities. Railroads have worked with the Department of Transportation to review and

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[6] Testimony of Joseph H. Boardman, Administrator, Federal Railroad Administration (FRA), U.S. DOT, before the U.S. Senate Committee on Commerce, Science, and Transportation.

[7] See National Transportation Safety Board (NTSB) Railroad Accident Reports, <www.ntsb.gov/Publictn/R_Acc.htm>.

[8] FRA, "Regulatory Assessment; Regulatory Flexibility Analysis – Hazardous Materials: Enhancing Rail Transportation Safety and Security for Hazardous Materials Shippers" PHMSA-RSPA-2004-18730, April 2008, 7.

[9] Presentation of Dr. Jay Boris, U.S. Naval Research Laboratory, to City Council, Washington D.C., October 6, 2003. This is a worst-case estimate based on specific climate conditions and a large outdoor event with many people in proximity to the release point. A less extreme scenario can be found in Anthony M. Barrett, "Mathematical Modeling and Decision Analysis for Terrorism Defense: Assessing Chlorine Truck Attack Consequence and Countermeasure Cost Effectiveness," PhD dissertation at Carnegie Mellon University, Department of Engineering and Public Policy, May 2009, discussed below.

[10] See Global Security Newswire, "U.S. Soldiers Exposed to Chlorine in Iraq," June 4, 2007, <gsn.nti.org/gsn/GSN_20070604_51B827B8.php>.

improve tank car design standards. Special speed limits and increased inspections on corridors with high volumes of hazardous materials traffic are other ways that railroads are modifying their handling of hazardous materials. Partly thanks to these efforts, over 99.9 percent of rail HAZMAT shipments reach their destination without a release caused by an accident.[11] In addition, railroad carriers have sought to raise rates to attempt to cover their risk exposure and to encourage product substitution and shorter movements, although these efforts are complicated by common-carrier regulations. Indeed, railroad companies cannot, by themselves, solve the problem.

Reducing the risk of TIH transportation is complicated by the diversity of the actors and stakeholders involved. Chemical producers and users initiate and receive shipments. Railroads as the carriers may bear most of the liability in case of a release; many railroads, therefore, would prefer not to carry any TIH products, but their common-carrier obligations under federal law prevent them from refusing, and limit the extent to which they can raise rates.[12]

Trade associations representing the chemical companies and the railroads lobby Congress and the regulatory agencies on behalf of their respective industries. A variety of regulatory agencies at the federal level oversee TIH transportation. The Federal Railroad Administration (FRA) is part of the Department of Transportation (DOT). Railroads and their TIH cargoes are subject to regulations of the Pipeline and Hazardous Materials Safety Administration (PHMSA) and the Surface Transportation Board (STB), both of which are part of the Department of Transportation, as well as the regulations of the Transportation Safety Administration (TSA), which is part of the Department of Homeland Security (DHS).

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[11] Association of American Railroads, "Hazmat Transportation by Rail: An Unfair Liability," <http://www.aar.org/InCongress/Safety%20and%20Security/~/media/AAR/PositionPapers/Hazmat%20by%20Rail%20September%202009.ashx>

[12] See, for example, the Surface Transportation Board (STB) decision affirming that Union Pacific (UP) was obligated to quote common-carrier rates and provide transportation service for chlorine to U.S. Magnesium LLC, although the railway argued that "the transfer would pose 'remote, but deadly, risks' as the material passed through high-population cities such as Chicago, Houston and Kansas City." Quoted in Global Security Newswire, "Rail Firm Opposes Some Chlorine Shipments," Wednesday, March 25, 2009, <gsn.nti.org/gsn/nw_20090325_3045.php>. The railway argued that common-carrier requirements did not apply because U.S. Magnesium had solicited rates for an unreasonable move over long distances and that alternative sources of chlorine were available; but this argument was unsuccessful. STB Docket 35219, June 11, 2009.

State and local governments have some authority over the railroad lines that may carry TIH through their jurisdictions. Local emergency responders, including firefighters and police, will be on the frontlines of any incident.[13] A major stakeholder is the public, because the public at large would be endangered if there is a TIH release.

Many corporate participants in the TIH supply chain, for reasons both of corporate social responsibility and of prudent business-risk management, have looked for ways to mitigate TIH risks. Major producers of chlorine gas are exploring collocation of the facilities that produce and those that use chlorine, in order to minimize the need for transportation of chlorine. Clorox plans to begin phasing out use of chlorine at all seven of its U.S. bleach production facilities.[14] Dow Chemical, the Union Pacific railway, and the Union Tank Car Company are among the companies collaborating in the Next Generation Railroad Tank Car Project to design safer tank cars. Chemical producers, railroads, and public safety officials have combined their efforts to improve emergency response in the event of a TIH release. End users are looking for substitute products. In the past decade, a number of wastewater facilities and drinking water plants have switched from the use of chlorine gas and other toxic purification agents to less toxic alternatives, but as yet these represent a fairly small proportion of the number of facilities nationwide that still use hazardous chemicals.[15]

Industry efforts to improve safety have not yet allayed all public concerns. The District of Columbia City Council took action in 2005 to block TIH from moving through its jurisdiction. The Council sought to keep TIH off the main rail line that crosses the District and passes within one mile of the Capitol, the White House, the Pentagon, and National Airport. The ban was successfully challenged by CSX, the freight railroad involved, with support of the Department of Justice, which argued that a local-level regulation such as this one was preempted by federal regulation under the Commerce clause of the Constitution.[16] At the federal level, these security issues are under study. The regulator of railroad safety, the Federal Railroad Administration, issued new regulations in 2009 on tank car design, routing, and operational practices. The regulator

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[13] Any of over 1 million first responders nationwide could be involved in a TIH incident.

[14] Global Security Newswire, "Clorox to Halt Use of Chlorine at Bleach Production Sites," November 2, 2009, <gsn.nti.org/gsn/nw_20091102_6428.php>.

[15] Paul Orum, *Preventing Toxic Terrorism: How Some Chemical Facilities are Removing Danger to American Communities*, Center for American Progress, April 2006.

[16] The U.S. Court of Appeals for the D.C. Circuit held that federal law preempted the city's effort to regulate the railroad. See CSX Transportation, Inc. v. Williams, United States Court of Appeals, D.C. Circuit, May 3, 2005, <bulk.resource.org/courts.gov/c/F3/406/406.F3d.667.05-5131.html>.

of railroad economics, the Surface Transportation Board, has heard arguments over whether the common-carrier obligation requires railroads to carry TIH traffic.[17] The Transportation Security Administration, which coordinates threat assessments and security inspections, issued new rail transportation security regulations in November 2008. Effective government regulation requires cooperation and coordination among all of these agencies.

### *Objectives and Outline*

The primary objective of this study is to describe and evaluate the policy alternatives that might effectively mitigate the dangers of transportation of toxic inhalation hazards, by internalizing the negative externalities of the TIH supply chain. In addition, this paper aims to be summary of information on the characteristics and risks of the TIH supply chain, providing a single source for stakeholders and policymakers. Section II describes the TIH risk by explaining the scientific basis of TIH danger, the complexity of the supply chain, and the risk features of accidents and terrorist attacks. Section III defines the TIH externality and shows why it is difficult to quantify the TIH risk; it examines general policy approaches to externalities from other arenas, and explores their applicability to TIH. Section IV details potential risk reduction strategies and approaches for each leg of the supply chain — production, transportation, and use. Section V concludes by summarizing policy options and assesses some of the most promising means to reduce the risks of transportation of toxic inhalation hazards.

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[17] See discussion below of the Union Pacific case brought before the STB by chlorine producer U.S. Magnesium. See Global Security Newswire, "Rail Firm Opposes Some Chlorine Shipments," Wednesday, March 25, 2009, <gsn.nti.org/gsn/nw_20090325_3045.php>.

## II. Risks in Transportation of Toxic Inhalation Hazards

Security concerns following 9/11 brought into focus the danger posed by the presence of hazardous materials near population centers. In this section, we describe the chemical properties of certain chemicals that make them particularly hazardous. Then, we outline the risks involved in transportation along the supply chain from manufacture to end-user. We describe a particular challenge to internalizing the risk externality: common-carrier regulations imposed on railways prevent them from refusing to carry TIH, which they might prefer due to the risk, and from imposing higher rates for carrying TIH to reflect that risk. The section then describes a number of railway accidents, including three TIH accidents that resulted in fatalities, and two other accidents involving hazardous (but not TIH) materials that further illustrate the potential dangers. The distinctions between accidents and potential terrorist attack are described and their implications for policy are explored.

### *Chemical Properties of Toxic Inhalation Hazards*

To understand the danger posed by TIH chemicals, it is useful to have a basic understanding of their chemical properties. This brief overview centers on chlorine and anhydrous ammonia, the most widely used and most transported TIH products.

Chlorine is a greenish-yellow noncombustible gas at room temperature and atmospheric pressure.[18] It is transported as a pressurized liquid. Chlorine gas is heavier than air, meaning that the gas settles into low areas when released into the open. It is chemically unstable and breaks down quickly when in contact with sunlight or water. Chlorine is used as a disinfecting agent for drinking water and waste water, and plays an important role in many manufacturing processes.

When chlorine is released into the air, it becomes very dangerous. Small doses irritate the eyes, skin, and respiratory tract; large concentrations of chlorine gas can kill people within minutes. If inhaled at very high concentrations, chlorine breaks down in the lungs to form hydrochloric acid that burns lung tissue, causing pulmonary edema and essentially causing drowning as liquid floods the lungs. The extent of chlorine poisoning depends on the quantity of gas, setting, time of exposure, and other circumstances. As

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[18] For more information, see U.S. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, "Draft Toxicological Profile for Chlorine," September 2007. < http://www.atsdr.cdc.gov/toxprofiles/tp172.pdf>

little as 3.5 parts per million (ppm) can be detected as an odor. The lowest lethal exposure is reported as 430 ppm for 30 minutes. Over shorter periods of time, exposure even to 15 ppm of chlorine causes throat irritation, while exposure to 50 ppm is dangerous, and exposure to 1000 ppm can be fatal after a few deep breaths. Frequent exposure to chlorine gas can degrade an individual's sense of smell; workers who have had occupational exposure to the gas are thus at greater risk of inhalational damage. The most effective countermeasure to exposure is to flush affected body parts with large quantities of water and move the victim to an unaffected area with clean air.

Anhydrous ammonia is a colorless gas characterized by a very sharp odor.[19] Anhydrous ammonia is lighter than air and invisible. It can be identified by its acrid odor, which is apparent even at very low concentrations. Ammonia is stored under pressure in rail tank as a liquid, but in the case of a rupture, the ammonia returns to a gaseous state and expands. Its primary use is as a fertilizer due to its high nitrogen content. It is applied directly and also used as a base for other fertilizer products.

Exposure to large quantities has severe health effects. Anhydrous means "without water," and anhydrous ammonia seeks water from any source, with corrosive results: its main toxic effect is severe burns to the moist parts of the body, such as the eyes, throat and lungs. Ammonia is less toxic at a given concentration than chlorine: exposure to greater than 50 ppm of ammonia causes mild irritation to the nose or throat. Exposure to 700 ppm or more causes such effects as coughing and severe eye irritation. Exposure to larger quantities can cause blindness and other severe or fatal injuries. Ammonia at 5,000 to 10,000 ppm is rapidly fatal to humans. The recommended response to ammonia release is to flood the area, and any persons affected, continuously with large amounts of water.

For these and other gases posing toxic inhalation hazard, the consequences of a release depend on the source, the surrounding terrain and meteorological conditions. The source determines the quantity of material released and duration of gas release. Meteorological conditions and the morphology of the surroundings influence the dispersion of the gas and the duration of exposure. These conditions include the amount of moisture in the air, wind direction and speed, amount of sunlight, terrain, and temperature. If the released TIH enters enclosed indoor environments, it can concentrate to fatal levels.

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[19] For more information, see U.S. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, "Toxicological Profile for Ammonia," September 2004. < http://www.atsdr.cdc.gov/toxprofiles/tp126.pdf>

Given these variations in a TIH release, responders such as railway employees, firefighters, and police must be made aware of the nature of any release and of other local conditions so that they can deal effectively with it.

### *TIH Supply Chain*

The complexity of the TIH supply chain poses challenges to chemical security and complicates any attempt at regulation, because stakeholders have divergent interests. The supply chains are different for each TIH chemical, involving diverse modes such as rail, truck, barge, and pipeline. In general, trucks carry the largest number of shipments, but rail moves more ton-miles.[20]

Producer-consumer geographical relations are also complicated. Chlorine, for example, is produced at chemical plants mostly concentrated in the southeast part of the country (see Figure 1) from which it is shipped to customer sites, such as water purification plants and other chemical plants. There are some cases in which chlorine is both produced and used at the same plant; this avoids exposure over long shipping times and distances. A chlorine user can sometimes also persuade a manufacturer to relocate nearby, in order to reduce transportation costs and risks.

The use of chlorine in large chemical plants and at water treatment sites results in a limited number of nodes in the transportation network (in contrast to the dispersed usage patterns of ammonia-based fertilizers described below). Even so, chlorine tank cars must travel significant distances. A tank car typically carries 90 tons of liquid chlorine. As Figure 1 shows, chlorine production is concentrated along the Gulf Coast and in a few other locations, but it is used at water treatment facilities and manufacturing sites all over the country. Many of these facilities are located in or near large cities, requiring chlorine transport through populated areas. This creates the need for long-distance carriage and potential exposure of large populations.

The economics of transportation favor rail transportation and indeed the majority of chlorine shipments in the United States are shipped by rail. The other safe and practical mode for long-distance transportation of chlorine is by barge, which is indeed considered to be safer than rail but is less available. Trucking companies are reluctant to offer long-

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[20] Annual liquid chlorine transport by truck totals approximately 500,000 tons, but these shipments tend to travel shorter distances than chlorine transported by rail, and are often shipped in smaller quantities. See Barrett, "Mathematical Modeling and Decision Analysis for Terrorism Defense."

haul chlorine transportation services[21] and since, unlike railroads, motor carriers are not subject to common-carrier obligations, they are therefore free to accept or decline shipper requests to transport TIH products or to charge very high prices (but perhaps non-competitive) prices to do so. Due to these factors, an estimated 85 percent of long-distance chlorine movements occur by rail.[22]

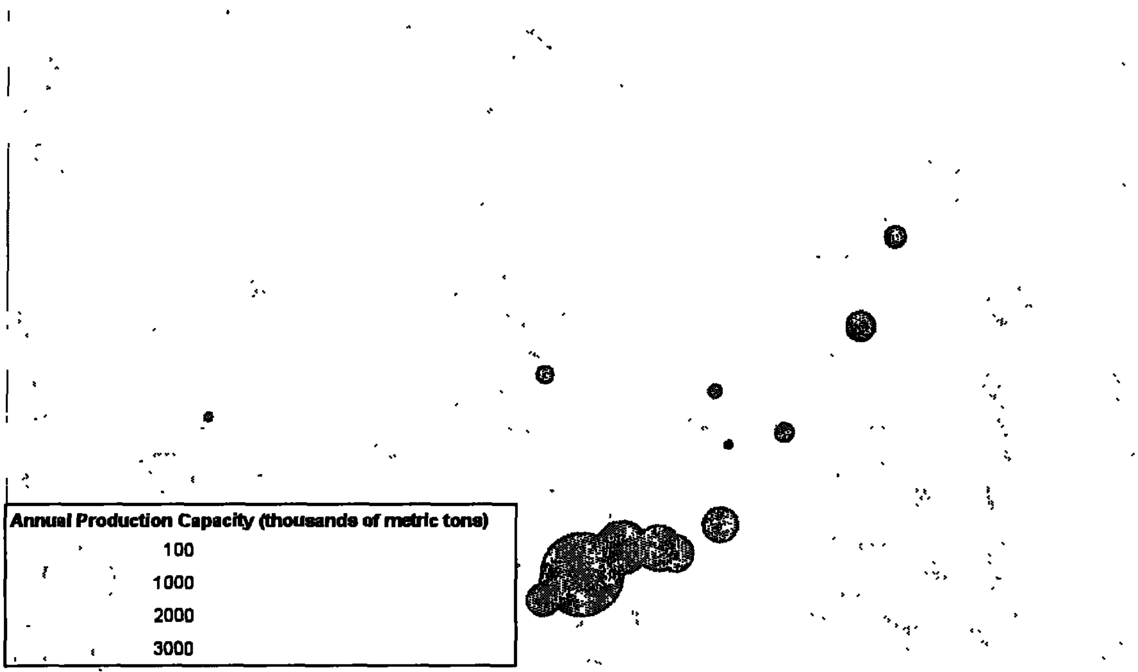


**Figure 1: Major U.S. Chlorine Plants, by Annual Production Capacity. (Source: ATSDR, "Draft Toxilogical Profile for Chlorine," September 2007)**

Ammonia is widely used throughout the main U.S. agricultural areas and thus, like chlorine, must be transported from a limited number of production and import locations to a large number of users. As Figure 2 shows, thirty-two plants in 19 states produced ammonia, with most production concentrated in Texas, Louisiana and Oklahoma, near sources of natural gas (the primary chemical feed stock for ammonia production).[23] A

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[21] Statement of Stephen J. Lube, CSX Transportation, STB Docket No. NOR 42100.

[22] Estimate by the Chlorine Institute, May 31, 2006, <www.americanchemistry.com/s_acc/bin.asp?CID=634&DID=2467&DOC=FILE.PDF.> Also see E.I. DuPont de Nemours and Co., Complainant's Opening Evidence, STB Docket No. 42100, February 11, 2008.

[23] Deborah A. Kramer, U.S. Geological Survey, Mineral Commodity Summaries, January 2005, p. 116, <minerals.usgs.gov/minerals/pubs/commodity/nitrogen/nitromcs05.pdf>.

large quantity of ammonia travels by pipeline and barge and most local distribution to farmers occurs by truck, but rail plays a vital long-haul transportation role.[24]

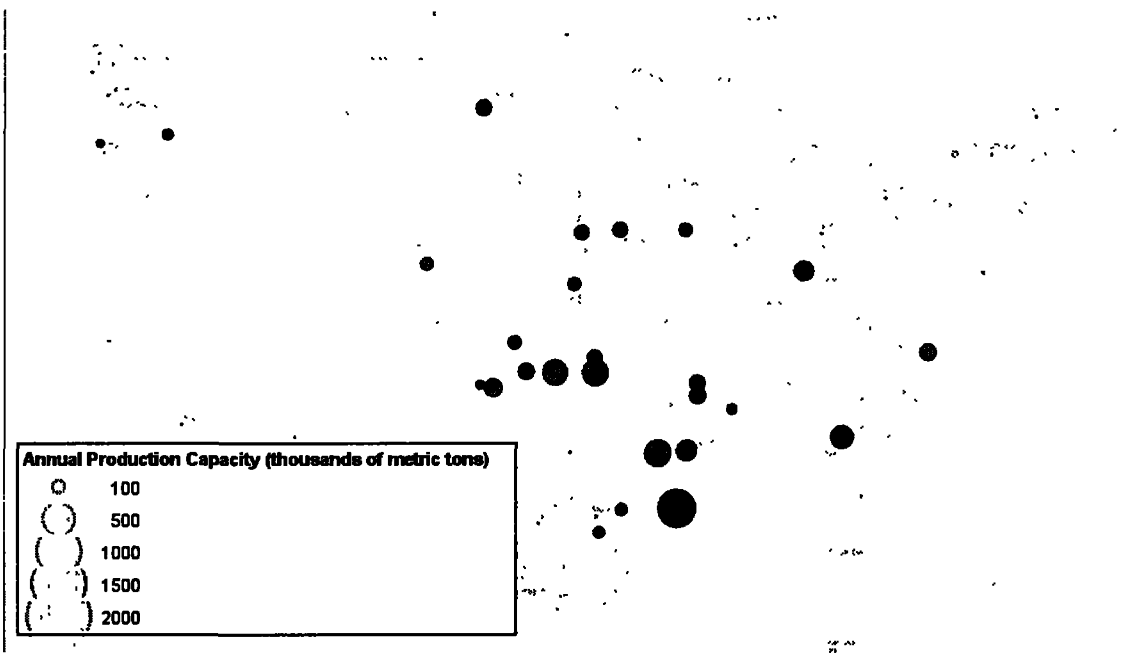


**Figure 2: Major U.S. Ammonia Plants, by Annual Production Capacity (Source: D. Kramer, "Nitrogen", U.S. Geological Survey Minerals Yearbook, 2002)**

Since various supply chain participants share responsibility for TIH transportation, this creates legal and liability complexity. A shipment of TIH may be owned by the producer of the shipment or by the end user, depending on the contractual arrangements. A railroad's contract for carriage may be with either the shipper or the receiver, or with an intermediary such as a broker. The railroad is almost never the legal owner of the product it is transporting, nor does the railroad typically own the tank car. Tank cars are mostly owned by the TIH shipper, or by a rail car leasing company.

Adding to these complexities, the shipment may be stored in a tank car for some time after delivery to the customer plant, waiting on a rail siding for unloading. There may be legal ambiguity over who is responsible for the contents of the tank car during this period. Seeking to resolve this ambiguity and ensure the continuous monitoring of hazardous materials involved, the Transportation Security Administration of the Department of Homeland Security set as a goal the establishment of a "secure chain of

[24] See, for example, Stephen J. Lube Statement, STB Docket No. NOR 42100. Major import locations for ammonia include Tampa, FL and Pascagoula, MS for shipment inland via truck and rail.

custody" for all TIH shipments, addressing this issue in a Rail Transportation Security Rule issued in November 2008.[25]

### *Rail Pricing Regulation*

If railroads could impose higher prices for transporting TIH than for transportation of other, less risky materials, TIH rates might reflect more accurately the potential costs of the risk of TIH accidents or other releases. Higher prices would, all else being equal, tend to decrease the number of rail TIH shipments and the ton-miles transported. In this section, we describe how this possibility is complicated by the current rail pricing regime.[26]

It is difficult to know exactly how expensive it is to ship TIH materials. In most cases, rail rates are set by contract between the shipper and the railroad and are not published. These contract rates, driven by supply and demand as well as the relationship between the negotiating parties, are not subject to regulation, because the railroad is deemed to be acting as a private or contract carrier. However, if shipper and railroad are unable to agree on a contract rate, the railroad is required to publish a "common carrier rate" for the movement in question, without discrimination as to the identity of the shipper or the material being shipped.

Although contract rates are not published, the published common carrier tariffs for TIH shipments are several times greater than those for comparable non-TIH chemicals. In 2008 rate case between a chemical company and a railroad, there was evidence that the railroad quoted a rate of $9,173 (including fuel surcharge) for transporting a tank car of chlorine from Niagara Falls, NY to New Johnsonville, TN.[27] Common carrier prices posted on the railroad website for transporting one tank car of caustic soda (a frequently shipped material that is hazardous but is not a toxic inhalation hazard) reveals rates of $3,707–4,634 per car (depending on the size of the shipment) for the same distance.[28] Analysis of public tariffs shows that the additional increments for longer distances

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[25] Rail Transportation Security Rule, Transportation Security Administration (TSA) of the U.S. Department of Homeland Security (DHS), 49 Code of Federal Regulation (CFR), Parts 1520 and 1580, Rail Transportation Security: Final Rule, November 26, 2008.

[26] The current rail pricing regulation regime is a result of the partial deregulation enacted under the Railroad Revitalization and Regulatory Reform Act of 1976 and the Staggers Act of 1980.

[27] DuPont Opening Evidence, STB Docket No. 42100.

[28] Movement of caustic soda from Niagara Falls, N.Y., to New Johnsonville, Tenn., <www.Shipcsx.com>, consulted May 28, 2009.

increase more steeply for TIH shipments than for non-TIH shipments. The rate differential suggests that rail carriers may be trying to recoup part of the cost of the risk for TIH shipments, particularly over long hauls.

If a shipper wants to challenge a published rate, it brings a complaint before the Surface Transportation Board (STB), a three-member panel that is the economic regulator of the railroad industry.[29] Rate cases may be filed under one of several procedural methods. If the STB finds the carrier's rates to be excessive, the shipper is entitled to rate relief. However, calculations for STB adjudications are based on system-average costs that do not incorporate the unique handling and risk characteristics of TIH traffic.

Generally, the STB has shown itself to be more sympathetic to shippers than to rail carriers. In a recent chemical company complaint against a railroad concerning certain movements of chlorine, the STB ruled that the railroad's proposed rates were unreasonably high and ordered the railroad to establish lower rates and pay reparations to the shipper.[30] The railroad had failed to convince the STB to allow an adjustment for TIH chemicals that would more accurately have reflected the risks inherent in TIH transport. In a similar case in early 2009, a railroad refused to quote a rate for a shipment of chlorine on the grounds that this was not a reasonable movement request, given the availability of alternative chlorine manufacturers closer to the destination. When the case went before the STB as a common carrier case (rather than a rate case), the STB required the railroad to establish rates and to provide service for this shipment of chlorine.[31]

Thus, the current regulatory scheme means that the risks of carrying a product that could cause billions of dollars in damage and impose potentially huge liability on a railway in the event of a release are rarely reflected adequately in rail transportation rates. In other words, they remain externalities.

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[29] "The STB is an economic regulatory agency charged with resolving freight railroad rate and service disputes, reviewing proposed rail mergers, rail line purchases, constructions and abandonments. The Board also oversees Amtrak's on-time performance and has jurisdiction over other matters." <www.stb.dot.gov>.

[30] STB Decision Docket No. 42100, June 27, 2008. Whether an entity like DuPont qualified as a "small shipper" under the rules was a contentious topic in the STB hearings.

[31] See STB Docket No. 35219; see also Global Security Newswire, "Rail Firm Opposes Some Chlorine Shipments," Wednesday, March 25, 2009, <gsn.nti.org/gsn/nw_20090325_3045.php>. Note that a common carrier case is meant to establish whether the railroad can refuse to carry the traffic in question, while a rate case determines the tariffs the railroad may charge.

*Accidents*

An essential step towards ensuring secure transportation of TIH products is minimizing the risk of accidental releases. Recent events highlight issues that must be addressed as part of the risk-reduction process. Three fatal accidents involving TIH product release have taken place in the past decade: at Minot, South Dakota, in 2002, at Macdona, Texas, in 2004, and at Graniteville, South Carolina, in 2005. In addition, a 2001 accident in a tunnel near downtown Baltimore, Maryland, although causing no fatalities, showed the potential danger of a HAZMAT accident in an urban setting. A 1987 New Orleans case suggests the vast potential exposure to liability claims in the event of an incident. These events are described in this section.

*Minot, North Dakota, January 2002: Anhydrous Ammonia Release*

On January 18, 2002, at 1:37 AM (CST), a Canadian Pacific (CP) train derailed half a mile from the city limits of Minot, North Dakota. Of a total of 112 cars, 31 cars, numbers 4–34, derailed.[32] The train "consist" included 39 HAZMAT cars, including 15 tank cars of anhydrous ammonia that were positioned as cars 18 through 32. All of these cars derailed, and five of them ruptured catastrophically. Tank car fragments were propelled up to 1,200 feet from the track, and 146,700 gallons of anhydrous ammonia — almost the entire contents of the five tank cars — were released almost instantaneously. Ammonia vapor spread five miles downwind over an area where 11,600 people lived.

Within minutes of the accident, the conductor notified the Canadian Pacific dispatcher in Minneapolis, Minnesota, and called 911 on his cell phone. By 1:41 AM, less than five minutes after the accident, emergency service operators were telling residents who phoned seeking information to shelter-in-place, by staying in their homes, closing windows, running showers, and breathing through wet cloths. By 5:30 AM, the vapor cloud had begun to dissipate. Emergency responders then began to evacuate residents.

The National Transportation Safety Board, after an extensive investigation, blamed the accident primarily on an "ineffective Canadian Pacific Railway inspection and maintenance program that did not identify and replace cracked joint bars [on the rails]

[32] All information for this section, unless otherwise cited, from National Transportation Safety Board, "Derailment of Canadian Pacific Railway Freight Train 292-16 and Subsequent Release of Anhydrous Ammonia Near Minot, North Dakota — January 18, 2002," NTSB Railroad Accident Report NTSB/RAR-04/01, <www.ntsb.gov/publictn/2004/RAR0401.pdf>, hereafter cited as "NTSB Report—Minot."

before they completely fractured and led to the breaking of the rail at the joint."[33] Tank car failure also contributed: the five cars that experienced catastrophic failure were constructed of non-normalized steel, which was more prone to cracking at the low temperatures found at the time of the accident.[34]

Public notification issues affected the consequences: many residents did not hear the city's emergency broadcasts because of power outages, and did not hear warning sirens because they were too far away. Authorities were initially unable to communicate with local radio stations to request emergency broadcasts; the local television station had no staff on duty.

The accident caused one death, due to anhydrous ammonia inhalation; the victim had become disoriented while trying to flee the area immediately following the accident. Eleven residents suffered serious injuries; 322 train crew, residents, and first responders had minor injuries. Equipment damage reported to the NTSB totaled $2.5 million and environmental cleanup costs were $8 million. Valuation for property damage and casualties is not available.

Following the Minot accident, the NTSB made several recommendations to improve track inspections and maintenance. The NTSB also made recommendations for improved tank car safety, including a call for a comprehensive analysis to determine the impact resistance of the steels in the shells of tank cars constructed before 1989. Ultimately, the NTSB recommended development and implementation of tank car fracture toughness standards.

*Macdona, Texas, June 2004: Chlorine Gas*

At 5:03 AM (CDT) on June 28, 2004, near Macdona, Texas, a Union Pacific (UP) train traveling at 44 mph passed a stop signal and collided with the middle of a Burlington Northern Santa Fe (BNSF) train that was leaving the mainline and entering a siding.[35]

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[33] Ibid., vi.

[34] Non-normalized steel was common in tank cars constructed before regulations were tightened in 1989. Normalization of steel is a metallurgic process by which the steel is heated to extreme temperatures and then air-cooled, increasing the metal's toughness and resistance to cracking at low temperatures. The outdoor temperature at the time of the Minot accident was -6°F. The anhydrous ammonia had been loaded at 40°F and was insulated. It was calculated that by the time of the accident, the temperature of the shell was 36°F and was thus below the ductile-to-brittle transition temperature for non-normalized steel.

[35] All information for this section, unless otherwise cited, from National Transportation Safety Board,

The four UP locomotive units and first 19 cars of that train were derailed, as were 17 cars of the BNSF train. The 16th car of the UP train, carrying liquefied chlorine gas, was punctured by the side of a UP flatcar that had derailed four cars ahead of it. As a result, 9,400 gallons of chlorine gas were released and formed a 1400-foot-diameter cloud, which then began to drift. The BNSF train crew notified both BNSF and UP dispatchers. It was later estimated that the chlorine concentration was 400,000 ppm near the accident scene, far above lethal levels (even 1000 ppm can quickly kill).

Within minutes of the accident, at 5:06 AM, a 911 call was made from a residence near the accident. For several hours, first responders and HAZMAT specialists arrived at the site. However, in part because of the high concentration of chlorine gas and due to the wreckage, it was not until 9:45 AM that an "entry team" in HAZMAT gear could begin attempting to rescue people trapped within the chlorine cloud. The accident resulted in three deaths, including the UP train conductor and two elderly local residents. The UP engineer, six emergency responders, and 26 residents were treated for injuries. Railroad equipment damages reported to the NTSB totaled $5.7 million; site cleanup costs were $150,000. Again, property damage values and compensation for victims is not publicly available.

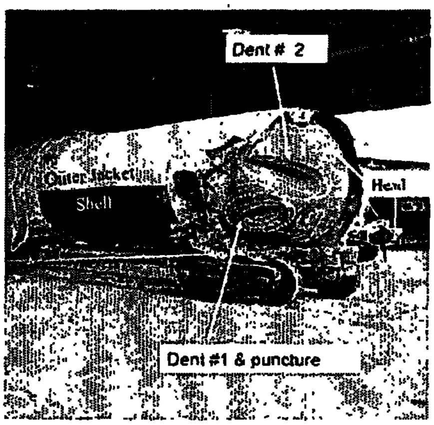


**Figure 3: Head Puncture in Macdona Accident (DOT, 2007)**

The NTSB concluded that neither the conductor nor the engineer of the UP train had fulfilled their duties. At the display of the "approach" signal, the engineer should have

"Collision of Union Pacific Railroad Train MHOTU-23 With BNSF Railway Company Train MEAP-TUL-126-D With Subsequent Derailment and Hazardous Materials Release Macdona, Texas June 28, 2004," Railroad Accident Report NTSB/RAR-06/03, <www.ntsb.gov/publictn/2006/RAR0603.pdf>, hereafter cited as NTSB Report—Macdona.

slowed the train to 10 mph in preparation for stopping to allow the BNSF train to proceed onto the siding. Instead, the engineer increased speed from 44 mph to 46 mph and continued to operate as if under a "clear" signal.

The NTSB blamed the "UP engineer's combination of sleep debt, disrupted circadian processes, limited sleep through the weekend, and long duty tours in the days before the accident," which, it said, "likely caused him to start the accident trip with a reduced capacity to resist involuntary sleep." The engineer (and other UP crew) likely experienced periods of sleep and were not sufficiently alert to respond correctly to the signals. The NTSB investigation also held that emergency responders had not reacted aggressively enough to rescue trapped residents: the road was blocked, but they had failed to consider alternatives.

The NTSB recommended that the Federal Railway Administration and the Union Pacific railroad study measures to limit crew fatigue. It also asked two unions — the Brotherhood of Locomotive Engineers and Trainmen, and the United Transportation Union — to raise awareness among their members regarding the importance of rest. The NTSB also suggested that the FRA consider revising certain operating measures; for example, the NTSB recommended positioning tank cars at the back of trains to minimize impact forces. It also reiterated recommendations made after the Minot accident to improve tank car design, although the tank cars involved at Macdona met the highest existing standards. The NTSB also noted that positive train control technology (discussed further below) could have prevented the Macdona accident.[36]

*Graniteville, South Carolina, January 2005: Chlorine Gas*

With nine deaths and over 500 injuries, the January 6, 2005, accident at Graniteville, South Carolina, was the most serious of the fatal railway releases of TIH.[37] Norfolk Southern (NS) train 192 collided with another NS train that was parked on a customer

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[36] Positive Train Control (PTC) is the term used in the United States to designate a collection of systems designed to increase railroad safety by overriding the engineer's control of the train and automatically stopping the train in certain dangerous situations.

[37] All information for this section, unless otherwise cited, from National Transportation Safety Board, "Collision of Norfolk Southern Freight Train 192 With Standing Norfolk Southern Local Train P22 With Subsequent Hazardous Materials Release at Graniteville, South Carolina — January 6, 2005," Railroad Accident Report NTSB/RAR05/04, <www.ntsb.gov/publictn/2005/RAR0504.pdf>, hereafter cited as "NTSB Report—Graniteville."

side track at 2:39 AM EST, derailing both locomotives and 16 cars of the moving train. Three tank cars containing chlorine derailed, one of which was punctured.

The side track on which the accident occurred served textile manufacturing facilities of Avondale Mills, Inc. Investigations showed that the crew of the parked train had completed their duties but had failed to realign the switch back to the mainline track from the industry side track. Track in this area is non-signaled, known as "dark" territory in the railroad industry. Authority to use track in this area is conveyed by the dispatcher in Greenville, South Carolina. Train 192, approaching at 48 mph, collided with the train parked on the side track. The punctured chlorine car released a chlorine vapor cloud that extended at least 2,500 feet to the north of the accident site, 1,000 feet to the east, 900 feet to the south, and 1,000 feet to the west.

Emergency responders were dispatched. A reverse 9-1-1 notification told nearby residents to shelter indoors until entry teams of emergency responders could evacuate people affected by the gas release.[38] An additional 5,400 people within a one-mile radius of the site were evacuated by law enforcement personnel. Over the next days, HAZMAT teams sealed the punctured car and removed hazardous materials from the site.

The accident caused nine deaths. Among the fatalities were the NS train engineer, six Avondale Mills employees, a truck driver, and a local resident. Approximately 554 people were taken to local hospitals, and 75 were admitted for treatment. All casualties were due to chlorine exposure; the NTSB concluded that the accident might have been non-fatal if not for the chlorine release. In addition, property damages reported to the NTSB totaled $6.9 million; a later FRA analysis estimated that the total cost of the accident was $126 million, including fatalities, injuries, evacuation costs, property damage, environmental cleanup, and track out of service.[39]

The NTSB investigation determined that the cause of the accident was the failure of the crew of the parked train to realign the switch after the crew completed its work. The crew, running up against its 12-hour duty limit, had rushed the completion of its tasks.

Following the accident, several railroads modified operating procedure to require that crews confirm the switch position to the dispatcher before signing off duty. The FRA

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[38] Reverse 9-1-1 is a notification system by which authorities can initiate automated recorded calls to citizens to notify them of an imminent hazard.

[39] FRA, "Regulatory Assessment; Regulatory Flexibility Analysis – Hazardous Materials: Enhancing Rail Transportation Safety and Security for Hazardous Materials Shippers" PHMSA-RSPA-2004-18730, April 2008.

issued a safety advisory asking railroads to review switch procedures. In the face of repeated accidents throughout 2005 caused by misaligned switches, the NTSB viewed these measures as insufficient. Upon conclusion of its investigation of the Graniteville accident, NTSB recommended establishing mechanisms to remind crews of their duty to realign switches, such as an electronic device or a strobe light. The NTSB was also concerned that although train 192 was traveling under the speed limit, its speed did not give it sufficient time to react to the banner displaying the status of the misaligned switch. Therefore the NTSB suggested that reduction of train speeds in non-signaled territory be considered, to give train crews more time to react to misaligned switches.

*Baltimore, July 2001: Tunnel Fire*

The three accidents described above all occurred in areas of relatively sparse population and early in the morning. By contrast, a 2001 rail accident that involved hazardous materials (HAZMAT) but not toxic inhalation hazards (TIH) occurred in an urban setting in the middle of the afternoon. On July 18, 2001, eleven of sixty cars in a CSX freight train derailed while passing through the Howard Street Tunnel in downtown Baltimore, Maryland, at 3:08 PM EST.[40] The train included eight tank cars loaded with hazardous materials; four of these were among the cars that derailed. One of the derailed tank cars contained tripropylene, two cars hydrochloric acid, and one car di-phthalate. A leak in the car containing tripropylene resulted in a chemical fire. A break in a water main above the tunnel flooded both the tunnel and the streets above it. The tunnel collapsed. Damage and cleanup costs reported to the NTSB from this accident totaled $12 million.

Although there were no serious injuries or casualties, this incident illustrates the risks of rail transportation of hazardous materials through urban areas. It also underlines the challenges of emergency response.[41] The city sounded emergency sirens, but many

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[40] See National Transportation Safety Board, "Railroad Accident Brief: CSX Freight Train Derailment and Subsequent Fire in the Howard Street Tunnel in Baltimore, Maryland, on July 18, 2001," <www.ntsb.gov/publictn/2004/RAB0408.pdf>, hereafter cited as "NTSB Report—Baltimore." The NTSB's investigation was unable determine the cause of the accident. Further information and sources in report prepared for DOT, "Effects of Catastrophic Events on Transportation System Management and Operations," <www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/13754_files/13754.pdf>. See also Arnold M. Howitt and Herman B. Leonard, *Managing Crises: Responses to Large Scale Emergencies* (Washington, D.C.: CQ Press, 2009), pp. 201–233.

[41] Stephanie Shapiro, "CSX train fire sparks debate of stay or go," *The Baltimore Sun* <www.dailypress.com/features/arts/bal-to.disaster21jul21,0,4656728.story>. See also Howitt and Leonard, *Managing Crises*, pp. 201-233.

residents did not know that the sirens meant they were to return home to seek information from television and radio, which would have told them to shelter in place. Instead, many residents chose to evacuate the area.

"Human behavior has to be taken into consideration when managing an emergency or disaster," said John Bryan, retired chairman of the department of fire protection at the University of Maryland's engineering school.[42] Announcements about the threat must, he said, be specific. Public education and establishment of public trust in police and other emergency responders are essential so that residents will follow directions from the authorities in case of a HAZMAT or TIH incident.

*New Orleans, 1987: Rail Yard Fire*

A 1987 case illustrates the issues that arise when there are many players that might be blamed for a HAZMAT accident. In 1987, an unattended rail car in the CSX yard in New Orleans leaked butadiene, a petroleum product, causing a fire that prompted authorities to order road closings and large-scale evacuations.[43] There were no serious injuries or deaths, and minor injuries were not conclusively linked to the fire. Nevertheless in 1997, in a class action suit brought by nearby residents that charged negligence, a jury awarded plaintiffs compensatory damages of $2 million for actual harm, and imposed additional punitive damages totaling $3.4 billion. Named in the suit were CSX, which owned the track where the tank car was parked, the shipper, other railroads that had moved the tank car (including Alabama Great Southern Railway which had actually moved it to the CSX yard), and a previous owner of the tank car, Phillips Petroleum Company, which had improperly installed a gasket that was blamed for the leak (however, Phillips could not be found liable under certain terms of Louisiana HAZMAT law).

Most of the punitive damage award ($2.5 billion of the total $3.4 billion) was imposed on CSX, despite its argument that it did not make the problem tank car, did not own it, and did not install the faulty gasket. CSX had not loaded the butadiene, and did not even move the car after it was dropped off at CSX's interchange yard. CSX was the owner of the track where the tank car was parked, and was scheduled to move it later to Chattanooga, Tenn. Nonetheless, CSX faced a punitive damage claim of $2.5 billion, and additional punitive damages were awarded against other defendants, including the

[42] Shapiro, "CSX train fire sparks debate of stay or go."

[43] Carol Marie Cropper, "Jury in CSX Case Sent Angry Message with a $3.4 Billion Stamp," *New York Times*, September 15, 1997, <www.nytimes.com/1997/09/15/business/jury-in-csx-case-sent-angry-message-with-a-3.4-billion-stamp.html>.

railroads that had moved the tank car, the shipper, and the tank car company GATX. The damage awards were challenged successfully on appeal and reduced from $2.5 billion to $850 million. Nonetheless, this case illustrates the potentially enormous liability exposure of railways carrying hazardous substances.[44]

### *Terrorism*

Secure transportation of TIH chemicals requires protection against terrorist attacks as well as accidents. To date, no hazardous materials release from a railroad in the United States has been caused by a terrorist attack. The Federal Bureau of Investigation has reported, however, that terrorists are specifically interested in "targeting hazardous material containers" by attacks on rail cars on U.S. soil.[45]

Richard Falkenrath, former Deputy Homeland Security Adviser to President Bush and current Deputy Commissioner of Police, New York City, made this assessment of the severity of the terrorist threat of TIH transport through urban areas by rail and truck:

> Of all the various remaining civilian vulnerabilities, one stands alone as uniquely deadly, pervasive and susceptible to terrorist attack: industrial chemicals that are toxic when inhaled, such as chlorine, ammonia, phosgene, methyl bromide, and hydrochloric and various other acids. These chemicals, several of which are identical to those used as weapons on the Western Front during World War I, are routinely shipped through and stored near population centers in vast quantities, in many cases with no security whatsoever. A cleverly designed terrorist attack against such a chemical target would be no more difficult to perpetrate than were the September 11 attacks. The loss of life could easily equal that which occurred on September 11 — and might even exceed it. I am aware of no other category of potential terrorist targets that presents as great a danger as toxic industrial chemicals.[46]

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[44] See "CSX Says Court Reduced Damage Verdict," *New York Times*, November 17, 1999, <www.nytimes.com/1999/11/17/business/csx-says-court-reduced-damage-verdict.html>.

[45] Richard Falkenrath, "We Could Breathe Easier: The Government Must Increase the Security of Toxic Chemicals in Transit," <www.washingtonpost.com>, March 29, 2005, p. A15.

[46] Falkenrath, "We Could Breathe Easier." However, railroad industry officials point out that it would be difficult for terrorists to coordinate an attack against a moving freight train, although perhaps less difficult against a stationary target.

Chlorine has been used as a weapon; it was used extensively in chemical warfare in World War I. In Iraq, insurgents have exploded small canisters of chlorine in trucks filled with explosives.[47]

An important distinction from accidental release is that a terrorist attack involving TIH could be deliberately targeted in such a way as to cause a high number of casualties. A worst-case scenario simulation performed at the Naval Research Laboratory concluded that if such an attack occurred during a celebration or political event in a setting similar to the National Mall, over 100 people per second might die, and up to 100,000 people could be killed within 30 minutes.[48] A July 2004 study by the Homeland Security Council (a White House office) estimated that even under less crowded conditions, a TIH attack in an urban area could result in as many as 17,500 deaths, 10,000 severe injuries, and 100,000 hospitalizations.[49]

A study by the National Research Council addressed a more conservative scenario: a terror attack on stored toxic chemicals in an industrial city, with a release of TIH materials in large (but unspecified) quantities.[50] The release was assumed to occur at midnight under mild meteorological conditions, resulting in a predicted 1,000 deaths and 22,000 injuries. The study also addresses release from a TIH rail car under similar circumstances, but it concludes that: "because of the quantity of chemical involved, multiple attacks at multiple sites would be required to produce numbers of casualties that would be considered catastrophic by the standards indicated in U.S. Department of

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[47] In the attacks in Iraq, fewer people were killed by the chlorine than by the explosives. The deadliness of the released chlorine gas is thought to have been reduced by chemical reactions resulting from the high temperatures of the explosions. The Iraq explosions were not "chlorine bombs." said Steven Kornguth, director of the biological and chemical defense program at the University of Texas in Austin. "They are putting canisters of chlorine on trucks with bombs, which then puncture the canisters and release the chemical," Kornguth said. "But it hasn't been very effective because the high temperature created by the bombs oxidizes the chemical. making it less dangerous."

[48] Boris presentation to D.C. City Council; see also Jay Boris, "The Threat of Chemical and Biological Terrorism: Roles for HPC in Preparing a Response," *Computing in Science and Engineering*, Vol. 4, No. 2 (March/April 2002), pp. 22–32.

[49] "Planning Scenarios: Executive Summaries Created for Use in National, Federal, State and Local Homeland Security Preparedness Initiatives," The Homeland Security Council. July 2004, Scenario 8.

[50] National Research Council, Committee on Assessing Vulnerabilities Related to the Nation's Chemical Infrastructure, *Terrorism and the Chemical Infrastructure· Protecting People and Reducing Vulnerabilities* (Washington, D.C.: National Academies Press, 2006), also available online at <www.nap.edu/catalog/11597.html>.

Homeland Security (DHS) National Response Plan."[51] However, this conclusion seems implausible, as it assumes that terrorists would choose to attack at midnight; it is more likely that terrorists would choose to attack when streets are crowded. If so, this scenario would have predicted far more than 1,000 deaths.

The scale of potential fatalities is confirmed by the sophisticated and comprehensive analysis in a recent dissertation that examined the consequences of a 17 ton chlorine terror attack on a tanker truck.[52] The study takes as its base case the rupture of a tanker truck carrying 17 tons of liquid chlorine in a generic urban area during daylight. While the analysis of the effect of structures on the three-dimensional propagation of the chlorine plume is less detailed than the Boris study and is, unlike that study, not specific to a particular city, the behavioral model is more detailed, and accounts for both the rate at which people can escape from open spaces and the extent to which sheltering in place saves (or sometimes may cost) lives. In the absence of a fast and effective defense response and with 2.5 meters/second wind speed, and a specified wind stability, approximately 4,000 fatalities are estimated, half within 10 minutes, and up to 30,000 fatalities, half within 20 minutes, depending on the dose response model. Fatality consequences are found to be roughly proportional to the amount of chlorine released, so a ruptured 90 ton rail car would, under a reasonable range of conditions, kill approximately 5 times as many people as would release of 17 tons from a truck. Assumptions for this range of estimates (4,000 to 30,000 fatalities depending on dose-response assumptions) is based on an outdoor population density in the target area of only 7 percent of the total daytime population density, it suggests that the Boris estimate of up to 100,000 deaths from a successful rail car attack is not as excessive or unsubstantiated as some critics have claimed.

Intelligence about terrorist intentions and capabilities is highly uncertain, which makes it quite difficult to estimate the likelihood of a terrorist attempt to rupture a TIH tank car in a crowded urban area. Several scenarios are conceivable for terrorist attacks on TIH-carrying trains. An implanted explosive weapon might detonate a rail car, perhaps when the car is motionless and is not in a protected environment. Current procedures provide for inspection by railroad personnel to guard against this type of attack.

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[51] According to the National Response Framework, "A catastrophic incident is defined as any natural or manmade incident, including terrorism, that results in extraordinary levels of mass casualties, damage, or disruption severely affecting the population, infrastructure, environment, economy, national morale, and/or government functions." U.S. Department of Homeland Security, "National Response Framework," January 2008, < http://www.fema.gov/pdf/emergency/nrf/nrf-core.pdf>, p. 42.

[52] Barrett, "Mathematical Modeling and Decision Analysis for Terrorism Defense."

In another scenario, a projectile weapon might puncture a storage tank or a tank car. If someone attempted to do so with a rifle, release from the resulting small punctures would not be rapid; instead, a relatively slow release and dissipation of the product would limit the effect. More worrisome is the potential use of a heavier weapon, perhaps one delivering a shoulder-launched shaped-charge projectile from a great distance, which could create a large rupture.

Terrorists might attack infrastructure such as rails, bridges, or tunnels in order to derail TIH tank cars. The consequences are hard to predict; they would depend in part on whether the cars meet the current government standards for robustness, and on their location in the train. The effects of such an attack might be similar to the effects of an accidental derailment. It might be worse if terrorists chose time and place deliberately to expose a large population of potential victims to gas release. Planning for such an attack is not so easy, however, because of the uncertain schedule of most trains and the additional uncertainty of the presence or absence of a TIH tank car.

For terrorists to have high confidence that such an attack would be devastatingly successful, they would need access to tools comparable the computational meteorology tools used by the government to estimate consequences and plan responses. The attacker would need to know train loading, schedules, and routing information, and would have to find a time when one or more tank cars of TIH materials would pass up-wind of a large population, and when wind and moisture conditions were appropriate. Having confidence of optimizing such an attack would require a complex operation.

One means of discouraging such a terrorist attack is to deny the possibility of a lucrative target, by ensuring that rail cars transporting TIH never pass through highly populated areas, at least not when those populations are likely to be out of doors. Shipping TIH only at night, or rerouting around exposed populations, would greatly reduce the attractiveness of targets.[53]

Denial of an attractive target could also be enhanced by assuring a more effective response to attack, in order to mitigate death and injury. Key components of effective response include a very fast situational assessment, combined with means to warn people in exposed places and to give them appropriate directions for protective action (such as sheltering in place or evacuating in the safest direction). This would require a much better program of public education in disaster response behavior than is in place today in U.S. cities.

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[53] This would, however, introduce significant operational complications for the railroads, discussed below in Section IV.

Currently the plan for responding to a TIH release assumes that emergency operations officials would have about 15 minutes to understand the nature of the threat, including meteorological and other information, and that first responders would therefore have 15 minutes to arrive on the scene prepared with appropriate equipment and information to mitigate the consequences.[54] However, this is not fast enough. There are simulation models that could provide essential information more quickly. The Office of Naval Research (ONR), for example, has constructed a simulation model called FAST3D-CT which can rapidly predict, with accurate details, the intensity and movements of a contaminant cloud, taking into account the specific morphology of the surrounding city streets and buildings.[55] However, it requires very fast computing facilities that are unavailable to most cities. The ONR team has found they can overcome this difficulty and greatly reduce the time to compute by running scenarios in advance for many cities, computing the consequences of a range of threats and meteorological situations. Then the detailed local conditions can be entered into a more modest computer to make the local corrections very rapidly. However the ONR model is not yet widely implemented.

Increasing the security of TIH transportation requires cooperation of the railways, the chemical industry, federal and state regulators, a challenge that is compounded by the ambiguity and uncertainty surrounding the magnitude of the risk, as the next section explores.

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[54] Private communication to Lewis Branscomb from Jay Boris, Naval Research Laboratory, Washington DC, Spring 2009.

[55] Boris, "The Threat of Chemical and Biological Terrorism," Boris presentation to D.C. City Council.

## III. Policies for Dealing with Externalities

The full societal cost of TIH transportation — including the risks of potential damage from accident or attack — is not reflected in the market prices for TIH products. A calculation of the full social cost of TIH transportation would include both the probabilistic costs of the consequences of TIH releases and the costs of countermeasures implemented to reduce the frequency and potential effects of a release. Economists described such costs as negative externalities. The discrepancy between the market price and social cost is the TIH safety and security externality.

The extent of the externalities — the degree of this misalignment of costs and benefits — is disputed among shippers and railroads. Railroads argue that rates for TIH, although they are already higher than those for other commodities, are not high enough to fully cover the probabilistic costs of an unintended release. Therefore, the railroads argue, they bear disproportionate risks while being forced to carry TIH by their common-carrier obligations.[56] Many shippers counter that shippers should not be responsible for the consequences if a release were to occur due to actions by railroad employees, such as at Graniteville, or is exacerbated by railroad equipment conditions, such as at Minot.

The public at large is endangered by transportation of TIH. As the accidents in Minot, Macdona, and Graniteville demonstrate, the potentially fatal consequences of TIH releases during rail transportation may fall upon the general public and, in this sense, external costs of TIH materials are borne by the public. The government and thus, ultimately, the tax-paying public also bears a portion of the costs of preparing for a possible TIH incident, including public education, emergency preparedness and specialized equipment and training, as well as the costs of emergency response and cleanup after a TIH release.

A sense of the risk from TIH transportation accidents can be drawn from the actual TIH release events described above. The damage valuations reported to the NTSB relating to train equipment range from $2.5 million in the case of the Minot accident to $12 million in the Baltimore case, with additional environmental cleanup costs ranging from $150,000 (Macdona) to $8 million (Minot). However these figures exclude casualties, private property damage, and interruption of business, which are necessary to evaluate the total value of all losses to the society from the accidents in question. In the case of the

[56] The railroads view TIH transportation as a "bet-the-company" risk, which they are unwilling to take on at any price. In this, the railroads demonstrate significant risk aversion.

Graniteville accident, the FRA estimated that the total cost of the accident, including loss of life, injuries, and evacuation costs, was $126 million. [57] This figure gives a more accurate sense of the magnitude of TIH costs. Indeed, total costs in all of the cited cases could -- under different circumstances -- have been far higher. The Graniteville accident, for example, took place in a rural setting, at an early morning hour. If a similar accident had occurred in an urban area in the daytime, there might be many casualties and severe economic disruptions, while a successfully targeted terrorist attack could have even more catastrophic effect.

If the TIH risk could be quantified and incorporated into the price of TIH products and their transportation, this would allow stakeholders to make economically rational decisions concerning production, use, and shipping of TIH chemicals. Better understanding of the sources of the risk would facilitate setting rational priorities for various risk-reduction strategies.

However, quantification of the TIH risk presents formidable challenges that hinder the development of comprehensive policies to deal with the externality. The challenges of quantification stem in part from the high degree of uncertainty surrounding possible TIH rail accidents, and the even greater unpredictability of a potential terrorist attack. Fatal TIH releases are generally considered to be low-probability high-consequence events, which difficult to predict but produce potentially devastating effects if they do occur.

Acknowledging these difficulties, in this paper we define the risk as the product of:

1. the probability of an accident or terrorist attack that results in a TIH release; and,

2. the probable consequences of a release, if one occurs.

This is the definition used by the U.S. Department of Transportation in its 1989 HAZMAT transportation guidelines (revised in 1994) and it is generally accepted as the starting point for risk calculation.[58]

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[57] FRA, "Regulatory Assessment; Regulatory Flexibility Analysis – Hazardous Materials: Enhancing Rail Transportation Safety and Security for Hazardous Materials Shippers" PHMSA-RSPA-2004-18730, April 2008.This analysis values fatalities at $27 million, injuries at $35 million, evacuation costs at $10.5 million, property damage costs at $6.9 million, environmental cleanup costs at $150,000, and track out of service time at $46 million.

[58] U.S. Department of Transportation, Federal Highway Administration, Office of Highway Safety, "Guidelines for Applying Criteria to Designate Routes for Transporting Hazardous Materials," FHWA-SA-94-083, September 1994.

The first component of risk, the probability of an incident of TIH release, is based on a number of factors. This discussion will focus on the risk stemming from accident, because the risk of terrorism is nearly impossible to quantify and will be discussed separately. The presence or absence of TIH cars in a train is not a major factor in the probability of an accident.[59] The probability of an accidental release is a function of the time and distance of exposure to risk, the quality of track and its signaling system, operating conditions (such as speed, single or double track, train routing, train control, train consist), quality of the rolling stock, and other factors. Human factors also play a role in many train accidents. Human errors exacerbated by excessive fatigue can be minimized by regulating working hours. At grade crossings where highway traffic intersects with rail tracks, many accidents are caused by motorists; such accidents are outside the railroads' control, and would be very difficult to quantify.

In the event of an accident, the second factor, the severity of the consequences, depends on various elements. The impact of a release will be influenced by the quantity of product released and the nature and toxicity of the specific chemical involved. The dispersion of the gas will be affected by the atmospheric conditions at the time of release, including the temperature, moisture in the air, and wind direction and speed. The spread of gas from the release site is also affected by the morphology of the terrain, the density of buildings, and the shape and direction of streets. Injuries and deaths caused by the release will depend on the number of persons and the duration of their exposure to the plume, which is a function of density of persons within the area, the size of the plume at toxic levels, and the speed at which persons affected can escape toxic levels. These factors are a function of time of day, the distance of that population from the release, the effectiveness of public response to emergency instructions, the rate at which people can move to safety, and the effectiveness of shelter-in-place.

The above elements of risk are relevant to a particular place and circumstance. To quantify risks for accidents in a network of rail links connecting many sources and delivery points of rail traffic, one must sum over the entire transit of a TIH train from loading point to product delivery. On the other hand, one could imagine dividing each link of a route into segments, each of which represents a different level of probability of accidents and the level of consequences based on the probabilistic analysis of a typical set of circumstances within each segment. The lowest risk segments could be analyzed by more simplistic assumptions, and the risk of the entire link could then be combined,

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[59] Human errors exacerbated by excessive fatigue can be minimized by regulating working hours. At grade crossings where highway traffic intersects with rail tracks, many accidents are caused by motorists; such accidents are outside the railroads' control, and would be very difficult to quantify.

based on length of the link and duration of exposure to accident. Conceptually, this allows a calculation of risk in terms of possible casualties. Practically, such a calculation would require gathering a broad range of information. As a practical matter, the result would be dominated by the higher risk segments on each link, and in urban areas at least one could expect a more complete risk analysis to be done by the local emergency operations authorities in the urban area in question. Perhaps more important, such an analysis would be used to compare the sensitivity of estimated risk and consequences to each of the analytical elements, thus supporting decisions on strategies to reduce risk.

***Policy Experience from Externalities Other Than Shipping Hazardous Materials.***

Lessons for dealing with the transportation of TIH and its safety and security externalities can be sought in policies that have addressed other externalities in the past. A variety of regulatory instruments seek to internalize external costs and protect the public. These include taxes such as the gasoline tax, emissions standards and market-based controls including cap-and-trade regimes (such as the Acid Rain Program), and limitations on liability and insurance schemes employed for nuclear reactors, oil spills, or bank deposits.

Perhaps the simplest way of addressing a situation in which private actors do not take into account the public consequence of their actions is to tax an offending activity or subsidize a beneficial activity. Taxes designed to change behavior (in contrast to taxes designed to raise revenue) are known as "Pigouvian" taxes, after the early twentieth century English economist Arthur Cecil Pigou. Pigouvian taxes work when an increase in the price of any existing good, service, or input into a production process leads to a decrease in its use. The magnitude of the change in usage generated by a Pigouvian tax depends on the availability of good substitutes, as well as the overall cost share of the input. As a consequence, while policy can predictably affect behavior through a Pigouvian tax, the magnitude of the impact will depend on the particulars of the situation. The better the available substitutes, the more effective the Pigouvian tax. An example might be the tax deductions granted owners of buildings installing green energy facilities during the Carter administration.

If the externality has the potential to be mitigated by new technology, policy could support research and development. The difference between this sort of subsidy and a Pigouvian subsidy is that an R&D subsidy is provided in an entirely different market from the one in which the external effect is present. In a technology-based approach for TIH, for example, a government-funded R&D program would subsidize firms that seek new approaches to accomplish industrial tasks while using smaller quantities of TIH chemicals. This type of policy strategy faces at least four obstacles. The first is the inherently uncertain nature of research, given that technical solutions cannot be counted on to materialize when they are needed. Second, and related, long time horizons may be necessary to research new technical options and put them into practice. Such timeframes put outcomes outside of the scope of accountability for corporate leaders, directors of federal agencies, or elected officials. Third, systems integration challenges confront industry supply chains. Modification of such large, complex technical systems can result in unintended consequences. The generic challenge of transitioning an invention into a market-ready innovation is exacerbated here by the difficulty of embedding an innovation into these complex systems. Fourth, absent regulatory restrictions or Pigouvian taxes on the existing technology, the incentive to adopt a new technology may be insufficient to induce its creation and adoption.

Taxes (sticks) and research subsidies (carrots) may be supplemented by other policy instruments. The arena of environmental regulation provides several examples. The government might simply limit the use of a toxic substance. For example, the Clean Air Act Extension of 1970 empowered the EPA to set binding emissions limits on new sources of specified common air pollutants. The EPA was required to base standards on the "best technological system of continuous emission reduction," that is, the state of the art in pollution control.

It can be a major challenge for the owner of an industrial facility to satisfy a complex set of federal environmental requirements imposed by different regulators with little or no coordination. While an inherent logic supported the notion that firms should utilize the "best available technology," the unintended consequence of such an approach was to create an incentive for regulated industries to oppose the development of new and improved anti-pollution technologies.

The challenge, therefore, was to achieve the desired aim of reducing the overall quantity of pollutants emitted into the environment while providing firms with incentives to achieve those reductions at the lowest cost. The approach to regulation that eventually resulted was the model of emissions trading, also known as cap-and-trade. In these programs, a mandatory emissions cap is set. Each emissions source, such as a power plant, must choose its own preferred avenue of compliance with standards. Each is permitted to trade its emissions allowances, which are priced by the market. This is coupled with a strict monitoring and inspection regime. This type of market-based solution creates incentives for companies to search for efficient solutions.

Perhaps the most successful experience with emissions trading programs have been the cap and trade programs for Sulfur dioxide ($SO_2$) and Nitrogen oxides (NOx), both administered by the EPA. $SO_2$ trading under the Acid Rain Program began in 1995, and initially targeted a subset of coal-burning power plants, later expanding to include more power plants.[60] Each year, a set number of allowances for permitted tons of $SO_2$ are distributed by the EPA, which makes a limited number of further allowances available at auction. These allowances may then be bought, sold, or saved for future use. In 2007, the total value of the $SO_2$ allowance market was approximately $5.1 billion, with an average nominal price of $325 per ton and 4,700 transactions moving 16.9 million allowances.[61] The goal of the Acid Rain Program is to reduce $SO_2$ emissions to 8.95 million tons, or 50 percent of 1980 levels, in 2010 (the cap as of 2000 was 9.5 million tons). Meanwhile, the $NO_x$ cap-and-trade program successfully reduced emissions to 60 percent below 1990 levels by 2002.[62] However there is a fundamental difference between these pollutants and TIH in that whereas risk is evenly distributed across the population in the former case, only a fraction of the population is exposed to TIH release.

In situations where a dangerous good is also important to the public interest, a liability or insurance scheme can distribute the risk. For example, the Price-Anderson Act was enacted in 1957 to facilitate the development of the nuclear power industry.[63] The Act, which required reactor licenses involving technical and operational requirements, created a federal pool of funds to compensate victims of a nuclear accident that might take place at any point in the supply chain, including transportation, storage, or reactor operation. To fund the Act, reactor licensees are required to have $300 million in private insurance; that sum is periodically revised based on the available amount of insurance.[64] In addition, in case of an incident with a cost exceeding $300 million, licensees would be obliged to contribute further at a rate of up to $10 million per year for each reactor, up to a maximum of $95.8 million. This creates a virtual secondary insurance pool of over $10 billion. If damages from a nuclear accident were to exceed the primary and secondary insurance coverage thus created, the government would, under the Price-Anderson Act have to propose a compensation scheme, which would require Congressional approval. The fund, administered by the Nuclear Regulatory Commission, has disbursed more than $200 million since 1957, $71 million of this related to the 1979 Three Mile Island accident.

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[60] U.S. Environmental Protection Agency (EPA), <www.epa.gov/captrade/documents/arbasics.pdf>.

[61] EPA, <www.epa.gov/captrade/allowance-trading.html>.

[62] Established in 1999 among a group of northeastern and mid-Atlantic states, the $NO_x$ program regulates emissions of power-generating facilities and industrial boilers during ozone season. See EPA, <www.epa.gov/captrade/documents/nox.pdf>.

[63] For background on the Price-Anderson Act, see GAO, "Nuclear Regulation: NRC's Liability Insurance Requirements for Nuclear Power Plants Owned by Limited Liability Companies," GAO-04-654, May 2004.

[64] All nuclear liability policies are written by American Nuclear Insurers [see note above.].

Oil spills have also been tackled by federal regulation through a liability mechanism. The 1989 Exxon Valdez oil spill was a catalyst for the Oil Pollution Act of 1990. It authorized the creation of the Oil Spill Liability Trust Fund, managed by the National Pollution Funds Center. The OSLTF is financed by industry via a tax of $0.05 per barrel of imported oil, interest on the Fund principal, assessed penalties, and cost recovery from responsible parties. The fund totaled a maximum of $2.7 billion as of 2005.[65] The OSLTF can be used for federal cleanup costs and to meet damage claims by government entities, corporations, or individuals.[66] If an accident occurs, the responsible party must cover cleanup and claims up to its liability limit (except that liability for a spill due to gross negligence is not capped).[67] Liability limits for accidents vary by vessel size; for example, the liability limit for a tank vessel of more than 3,000 gross tons is the greater of $3,000 per gross ton or $22 million.[68] Beyond the liability limit, responsible parties may present claims to the OSLTF for additional funding. However, the funds available from the OSLTF are limited to $1 billion per incident. The Oil Pollution Act also set operational mandates relating to vessel construction, crew licensing and manning, and contingency planning in order to reduce the risk of future accidents. This is similar in concept to the licenses required of reactors by the Price-Anderson act, combining technical and operational requirements with a financial liability scheme.

Other models may be found in the financial arena. An example of an insurance scheme is the Federal Deposit Insurance Corporation (FDIC), an independent government agency created in 1933 during the Great Depression to insure private accounts in commercial banks against bank failures.[69] Individual deposits are insured up to $100,000 (in late

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[65] The Oil Spill Liability Trust Fund (OSLTF) is described at <http://www.uscg.mil/npfc/About_NPFC/osltf.asp>.

[66] U.S. Department of Homeland Security, U.S. Coast Guard, "Oil Spill Liability Trust Fund (OSLTF) Funding for Oil Spills," January 2006.

[67] Other exceptions to the liability cap include failure to report the incident and violation of federal regulations: see U.S. Code Title 33, Chapter 40, Subchapter 1, Section 2704 "Limits on liability," <http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=browse_usc&docid=Cite:+33USC2704>. However the responsible party is not liable for costs and damages if the spill is caused by an act of God, an act of war, government negligence, or act or omission of a third party: see U.S. Code Title 33, Chapter 40, Subchapter 1, Section 1321, "Oil and hazardous substance liability," < http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=browse_usc&docid=Cite:+33USC1321>

[68] See the National Pollution Funds Center, "Oil Pollution Act (OPA) Frequently Asked Questions," November 6, 2009, <www.uscg.mil/npfc/About_NPFC/opa_faqs.asp#faq1>.

[69] See FDIC website, <www.fdic.gov/about/learn/symbol/index.html>; see also "Deposit Insurance: An Annotated Bibliography," <www.fdic.gov/deposit/deposits/international/bibliography/index.html>.

2008, this limit was temporarily raised to $250,000). Funding for the FDIC derives from fees banks are required to pay based on the volume of deposits they hold. FDIC funds are invested in U.S. Treasury securities. As of 2009, the FDIC insurance fund totaled over $17.3 billion and insured more than $4 trillion of deposits.[70] The FDIC is charged with monitoring member banks to ensure that they are meeting liquidity requirements. If a bank fails, the FDIC pays out for depositor losses, and also oversees the sale of the failed bank's assets and the settlement of its liabilities.

Another example of insurance, the Terrorism Risk Insurance Act (TRIA) of November 2002 (reauthorized in December 2006), was designed to solve a specific problem. After the events of September 11, 2001, the insurance industry was newly appreciative that terrorist attacks might occur and involve enormous potential liabilities. Thus they became reluctant to provide insurance coverage against terrorism for new commercial construction while, particularly in New York City, builders were unwilling to move forward with construction projects without such terrorism protections. Congress therefore agreed to underwrite terrorism risk insurance. Much like the Price-Anderson Act, TRIA pledged the resources of the federal government in order to encourage economic activity in an environment of pervasive risk. However, this step did not reduce those risks.

These various policy instruments all provide models for the TIH issue, and their potential applicability is evaluated below. First, however, we examine risk-reduction strategies that are applicable to TIH; these are comparable to policies such as the OSLTF and the Price-Anderson Act that impose operational requirements designed to enhance the safety of the underlying supply chain and reduce the risk of a catastrophic accident.

[70] See FDIC website, <www.fdic.gov/about/learn/symbol/index.html>.

## IV. Risk Reduction Strategies

Several broad areas of TIH transportation offer the potential for risk reduction, including changes in rail operations, improvements in tank car design, more effective emergency response, product substitution by TIH users, and relocation of TIH sources or users. Improvements can be achieved through a combination of voluntary initiatives by the railroads and their unions, together with government regulation. This section lays out the various options, and examines progress to date and potential for future action.

First, changes to rail operations may diminish the chances of a catastrophic accident, and may also reduce the opportunities for a terrorist attack. Rail safety improvement is an ongoing process that is in the interest of all stakeholders. Initiatives that have already been undertaken include modifications of rail equipment, such as tank car design enhancements, and development and installation of positive train control following a legislative mandate. Other risk-reduction measures might include changes to rail operations, such as rerouting, improved yard management, or repositioning the tank car within the train composition or "consist."

A second broad area for improvements is emergency response, to mitigate the effects of any incident. Better training for emergency responders that is specific to dealing with hazardous materials and TIH, appropriate equipment for such incidents, management of response infrastructure, information and training of the public and improved coordination among parties are critical, particularly in the case of an intentional or terrorist attack.

Another category of risk-reduction strategies involves product substitution and management of the supply chain (including modifying production and use locations) so as to minimize the need to transport TIH materials over long distances. This approach attacks the source of the risk directly, and would be the best long term risk reduction strategy, but could be the most difficult to achieve comprehensively because existing patterns of use and location of sources and users of TIH chemicals would be hardest to change.

### *Tank Car Design and Safety Improvements*

One area offering clear potential for risk reduction is tank car design. Recent accidents have underlined the need to develop better safety standards for tank cars and spurred both private industry and government regulators to address the design issue. However, stakeholders in the chemical and rail industry may have conflicting interests; together with uncertainty as to regulatory roles, this creates contentious issues relating to the quantification and assignment of costs and risks borne by each player.

The modern pressurized railroad tank car is designed to transport liquids in bulk, such as petroleum products, liquid chemicals, or liquefied gases. Tank car shells made after 1989 are constructed from rolled plates of TC-128 normalized steel. The shell is surrounded by insulation and enclosed in an outer jacket of steel, which keeps the insulation in place but adds little protection. A stub sill, which is the structural member for the couplers and draft gear and is also the attachment point for the wheel sets, is attached to the underside of the tank at each end. Brakes and other features are welded to pads, which are welded to the tank shell to improve stress distribution. The average cost of a tank car in 2008 was around $120,000.[71]

As of 2006, there were 275,000 such tank cars in use in the United States, representing 17 percent of the total railcar fleet.[72] Of these, 74 percent were owned by rail car leasing companies, 26 percent by shippers, and less than 1 percent by the railroads.[73] Tank cars vary considerably in design to make them appropriate for carriage of specific chemicals; only about one-fourth of the tank car fleet is approved for use with TIH chemicals.[74]

The accident record of rail tank cars is very good overall, despite the recent TIH rail accidents described above. However, these incidents highlighted the need to strengthen TIH tank cars. The National Transportation Safety Board found that deficiencies in the breached tank cars were a major cause of the 2002 accident in Minot, ND.[75] The ruptured tank cars were constructed before the 1989 rule change that required normalized steel in tank car construction; because they were made of non-normalized steel, they were therefore less resistant to puncture than newer cars.

Many recent efforts to improve tank car design were initiated in the private sector, prompted by the desire to preempt government regulation, to gain advantage over competitors, as well as ethical consideration, public relations benefits, and a focus on enterprise risk management.

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[71] See Comments by Olin Corporation, PHMSA Docket FRA-2006-25169, June 2, 2008, p. 1.

[72] D. Samples, "2008 and Beyond — Building for the Future," Union Tank Car Co., October 4, 2007.

[73] D. Samples, "2008 and Beyond — Building for the Future." The three largest tank-car leasing companies are the GATX Corporation, the Union Tank Car Company, and GE Rail.

[74] Patrick J. Krick, "Security, Capacity and Risk Management — The Case of TIH Products and Pressure Tank Car," 2006, (consulting company white paper), <www.thomasgroup.com/eLibrary/White-Papers/Security-Capacity-and-Risk-Management-The-Caseof-.aspx>.

[75] NTSB Report — Minot.

The Association of American Railroads Tank Car Committee (AAR-TCC) began to study the design of a safer tank car following TIH accidents of 2002-2005. Its goal was to develop a TIH tank car that would reduce the conditional probability (CPR) of TIH release upon impact by 65 percent.[76] In March 2008, the AAR set new standards for shell, tank-head, and top fittings.[77] These industry rules applied a higher DOT standard to various base types of tank car used for TIH carriage.[78] However these rules were later preempted by a January 2009 federal rule, described below.

Meanwhile, shippers, carriers, rail car builders, and government joined in an effort designated the Next Generation Rail Tank Car Project (NGRTC). The project included participation by Dow Chemical, Union Pacific Railroad, and the Union Tank Car Company (UTLX), as well as the Transportation Security Administration (TSA) of the Department of Homeland Security, the Federal Railway Administration (FRA), and its Canadian counterpart, Transport Canada.[79] The goal of the project was to design a tank car that would perform five to ten times better in a standardized test that measures the energy required to cause failure in a current tank car approved for carrying chlorine.[80] The NGRTC declared the "end of [the] evolutionary path for [a] 'thicker is better' approach," and instead considered options to modify the structural design of the current tank cars to increase impact resistance or shock absorption.[81] Added head protection measures, for example, would include either stronger head shields or deformable head shields to create "crumple zones" that would absorb more impact before the impact force could reach the TIH container. The non-structural outer layer of steel could be strengthened to provide additional crash protection, with incorporation of energy-

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[76] Conditional probability of release (CPR), the metric used by the AAR, is the estimated probability of release from a given tank car in the event of an accident.

[77] Ibid. For example, chlorine cars meeting minimum DOT specification for 105J500W cars with no head shield, head thickness of 0.787 inches, and shell thickness of 0.787 inches, would, according to the industry's new standard, have to comply with minimum specification 105J600W, with a full-height head shield and increased head and shell thickness (to 1.1360 inches and 0.9810 inches respectively). According to the AAR, the new requirements could be met using upgraded versions of the current tank cars.

[78] Association of American Railroads, "Docket No. FRA-2006-25169: Hazardous Materials: Improving the safety of railroad tank car transportation of hazardous materials: Comments of the Association of American Railroads." June 2, 2008, p. 8.

[79] See NGRTC Project, "Next Generation Rail Tank Car," presentation to Transportation Research Board (TRB), 87th Annual Meeting, January 16, 2008; and David Noland, "Safer Train Tank Car Tech Rolling Down the Line," *Popular Mechanics*, February 6, 2007.

[80] NGRTC Project, "Next Generation Rail Tank Car."

[81] NGRTC Project, "Next Generation Rail Tank Car."

absorbing layers. Within the shell, the tank support system could be modified to allow the tank to move more freely in case of impact, isolating it from crash forces. One the most promising and easiest design modifications would be improvement of fittings and valves. Reducing their profile or creating removable valves would decrease vulnerability in case of accident. The installation of real-time monitors on TIH cars to transmit information to control centers was studied, and shippers have begun to implement this measure.[82]

In August 2005, after the TIH rail accidents described above, Congress added a section of hazmat law to the SAFETEA-LU federal transportation authorization statute.[83] It required the FRA to develop and validate a predictive model for tank car accidents and to begin the rulemaking process for improved tank car standards.[84] These efforts resulted in new FRA regulations in early 2009 that raised standards for tank cars.[85]

FRA research has focused on evaluating accident survivability of tank cars through a modeling and testing process. The Volpe National Transportation Systems Center conducted a program of testing and modeling that eventually developed a concept design for a new type of tank car. The Volpe conceptual design is based on the use of sandwich panels of two sheets of steel, separated by an interior structure such as a honeycomb. Such panels can "support loads in the plane of the panel while offering effective energy-absorbing capability in the normal (out-of-plane) direction, as well as a high bending resistance."[86] Significant work remains to be done before a prototype car using this technology could be constructed.

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[82] RFTrax of Sugarland, Texas, is developing an Asset Command Unit for the NGRTC that uses GPS to track the tank car's position and sensors to detect the level of chemical product in the tank car; it transmits this information to shippers. Dow Chemical has installed GPS tracking on its TIH tank cars.

[83] See SAFETEA-LU, "Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users," text at <frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=109_cong_bills&docid=f:h3enr.txt.pdf>.

[84] HAZMAT is addressed in Title VII of SAFETEA-LU.

[85] U.S. DoT, Pipeline and Hazardous Materials Safety Administration (PHMSA), 49 CFR Parts 171, 172, 173, 174 and 179. "Hazardous Materials: Improving the Safety of Railroad Tank Car Transportation of Hazardous Materials; Final Rule," January 13, 2009.

[86] M. Carolan, B. Talamini, and D. Tyrell, "Update on ongoing tank car crashworthiness research: predicted performance and fabrication approach," Proceedings of 2008 Joint Rail Conference, Institute of Electrical and Electronics Engineers (IEEE) and American Society of Mechanical Engineers (ASME), April 22–23, 2008, p. 2.

The DOT nevertheless drew upon the Volpe research during the regulatory process that culminated in a Final Rule published in January 2009.[87] The rule requires better puncture resistance for TIH tank cars in either the inner shell or outer jacket, installation of full head shields, and enhanced protection for valves and fittings. It also set a 50 mph speed limit for loaded TIH cars and imposed a requirement to prioritize replacement of all tank cars built from non-normalized steel. The rule specified that these standards should be considered interim tank car standards, applying to all cars built after March 16, 2009. Even if later research and testing results in different standards, the rule specified that tank cars complying with the interim standards would be continue to be acceptable for 20 years under a "grandfather" clause. These federal standards explicitly preempt the AAR standards described above.

There was a long process of dialogue and debate among stakeholders before the terms of the final rule were settled. For example, a performance standard that would have required TIH tank cars to resist shell puncture at 25 mph and tank-head puncture at 30 mph was abandoned.[88] Since this had been based on the calculation that secondary car-to-car impact speed was approximately half that of the train speed, the 50 mph limit set in the final rule was expected to be adequate instead.[89] Ultimately, the final rule based standards on a chemical industry petition that proposed a commodity-specific scale-up in tank car specifications: each commodity, ranked by degree of TIH hazard, would require the next-strongest tank car, with thicker steel.

Another important point of debate involved speed limits. The FRA had found that a "disproportionate" number of accidents occurred in non-signaled or "dark" territory. The Proposed Rule therefore required a limit of 30 mph for TIH tank cars in dark territory, unless the tank cars conformed to the new, enhanced standards. However, the railroads argued successfully for dropping this standard, arguing that it would hinder service to the non-TIH customers that comprised the vast majority of traffic.

As of mid-2009, the FRA tank car regulation had not spurred demand for new cars.[90] American Railcar Industries blamed the economic slowdown: "We haven't seen much of

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[87] U.S. DoT, Pipeline and Hazardous Materials Safety Administration (PHMSA), 49 CFR Parts 171, 172, 173, 174 and 179. "Hazardous Materials: Improving the Safety of Railroad Tank Car Transportation of Hazardous Materials; Final Rule," January 13, 2009. Hereafter DOT Tank Car Final Rule.

[88] Based on the calculation that secondary car-to-car impact speed was approximately half of the train speed, this standard had been proposed in conjunction with the 50 mph speed limit.

[89] See Discussion in DOT Tank Car Final Rule, p. 1779.

[90] Argus Rail Business, "FRA tank car replacement rules fail to spur demand," June 22, 2009.

an impact form the FRA rule. Orders are pretty soft.... With the economy slowing down, shipments have slowed down."[91]

The final rule represented an incremental approach that was more palatable to railroad and chemical industry stakeholders. The rulemaking process highlighted the difficulty of resolving the competing interests of different stakeholders. Instead, cooperative programs such as the NGRTC could provide a valuable model for performing the research necessary to allocate long-term investments towards the more radical tank car enhancements that might do more to reduce the risk of a TIH release.

***TIH Train Re-routing and Re-scheduling***

The potential consequences of a TIH release depend on the severity of the accident and also on the location and time of the accident. One widely-discussed risk-mitigation proposal involves re-routing trains containing TIH tank car loads, for example, by choosing a route with less population exposure.

This risk-reduction strategy came to the fore in the midst of concern over rail security after the 9/11 attacks. TIH tank cars passing through major population centers were recognized as potential chemical weapons. Proponents of mandatory rerouting of TIH products argued that diverting trains around cities would place fewer people at risk of a terrorist attack, and would also decrease risks due to accident.

On the basis of this reasoning, in February 2005 the Washington, D.C., City Council enacted an emergency measure that banned transportation of hazardous materials within a specified "Capitol Exclusion Zone" with a radius of 2.2 miles from the U.S. Capitol.[92] D.C. Councilmember Kathy Patterson argued that, given D.C.'s high profile as a target, and a lack of appropriate federal action, it was imperative for local authorities to act. In highly publicized testimony, Dr. Jay Boris of the U.S. Naval Research Laboratory suggested a potential for enormous casualty rates if TIH were released in Washington during a daytime event that had attracted huge crowds to the Mall. Under this worst case, he estimated, there could be as many as 100,000 deaths within thirty minutes of a chlorine release near the Capitol.[93] The D.C. Council asserted that the ban would not impose an unreasonable burden on the railroad. Baltimore, Cleveland, Boston and other

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[91] Ibid.

[92] Walt Bogdanich and James Dao, "Legislators Move to Toughen Federal Rail Oversight," *New York Times*, February 2, 2005, <www.nytimes.com/2005/02/02/national/02rail.html>.

[93] Boris presentation to D.C. City Council.

cities considered implementing similar bans, but little effort was made to identify where the rerouted shipments would go instead.

CSX Transportation, Inc., owner of the rail line passing through the District, immediately filed a motion in federal court seeking suspension of the ban. CSX argued that the city's action violated the Commerce Clause of the U.S. Constitution and was preempted by existing federal law. CSX feared that if D.C.'s ban were upheld and other cities and counties followed, it would complicate railway operations and add significant extra costs especially to HAZMAT transportation.

CSX's initial challenge was at first denied in D.C. District Court in April 2005; the judge ruled that the D.C. ban did not conflict with federal law.[94] In early May 2005, however, the U.S. Court of Appeals for D.C. reversed that decision; ruling in favor of CSX, it held that an injunction to block the D.C. ban would be permitted.[95] There was public criticism of the decision on appeal, with calls for Congress to legislate mandatory HAZMAT re-routing to keep dangerous TIH chemicals away from government targets and population centers.[96]

The goal of any re-routing strategy should be to minimize both the risk and the impact of a TIH release. There are, however, many possible means to evaluate the route. Risk could be evaluated according to parameters that include least population exposed to TIH risk, shortest route by distance, shortest route by time, or safest track quality. Complicating the issue is that these criteria may be contradictory: for example, the shortest route might expose more people to a possible TIH release, or the route that puts the fewest people at risk might be a rural track of lower quality without signals, thus increasing the potential for an accident. Therefore, choice of re-routing criteria must involve careful evaluation to determine whether new routes actually represent a significant reduction of overall risk.

Rerouting is also complicated by the nature of the rail network itself, which is far less extensive than the highway network and therefore offers fewer route options.[97] Each individual rail carrier operates mostly over its own network, which is unlikely to have

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[94] Terrence Nguyen, "Judge rules in favor of DC HAZMAT ban," *Fleetowner.Com*, April 19, 2005, <fleetowner.com/news/dc_hazmat_ban_washington_041905/index.html>.

[95] CSX Transportation, Inc. v. Williams, United States Court of Appeals, D.C. Circuit, May 3, 2005, <bulk.resource.org/courts.gov/c/F3/406/406.F3d.667.05-5131.html>.

[96] "Washington's Deadly Bridge," *New York Times*, July 5, 2005, <www.nytimes.com/2005/07/05/opinion/05tue1.html>.

[97] Glickman, Erkut, and Zschocke, "The cost and risk impacts of rerouting railroad shipments of hazardous materials," p. 1016.

multiple efficient routing options. Cooperation with other rail companies would provide more rerouting options; however, it would also require interchanges among carriers. Interchanges involve switching, with greater risk of accidents, and they also impose administrative costs and loss of revenue for the railroad originating the shipment. In addition to the cost and complexity, and questions about which routing choice gives the greatest safety and security for the least cost, there will remain essential industries that can only be served by using track that lead through large cities.

Rail industry opponents of rerouting proposals have argued that moving TIH cars out of cities would not necessarily reduce overall risk of an accident.[98] Most tracks running through cities are of the highest quality, and are equipped with the best signaling systems. Moving TIH cars through cities often represents the most direct route, thus minimizing the distance the TIH must be shipped. The nature of the rail network makes it very difficult for most shipments to avoid cities; shifting TIH traffic to a more rural route might require carriage over less-safe track over greater distances, and for longer time in transit. Thus, seeking to decrease the likelihood of a terrorist attack by rerouting might, paradoxically, increase the likelihood that an accident might take place (although perhaps in an area where it would have consequences for fewer people). Thus whether overall risk would be reduced would depend on the relative balance between likelihood of an accident, which might be increased by rerouting, and the likelihood that a substantially smaller population would be exposed.

Several studies have attempted to assess the opportunities for improving safety by rerouting hazardous materials (HAZMAT). The Oak Ridge National Laboratory of the U.S. Department of Energy produced a framework and a Web/GIS tool for routing HAZMAT shipments.[99] This tool, designated "THREAT" (Tool for HAZMAT Rerouting Evaluation and Alternative Transportation), searches for routes to optimize specified objectives and calculates performance measures for those routes.[100] The routing engine incorporates GIS (global information system) data illustrating rail networks, HAZMAT data on commodity movement and characteristics, population data from the census, risk functions, and other parameters to generate routing solutions and route assessments.

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[98] AAR, "Mandatory HAZMAT Rerouting," <www.aar.org/GovernmentAffairs/~/media/AAR/PositionPapers/833.ashx>.

[99] Han, L.D., S. Chin, H. Hwang, and B.E. Peterson, "A Tool for Railroad Hazmat Routing under Shipment Bans in Major Cities," Proceedings of the 85th TRB Annual Meetings CD, Paper 06-1790, Washington, DC, 2006.

[100] Han, Chin, Hwang, and Peterson, "A Tool for Railroad HAZMAT Routing."

A 2006 case study applying this tool to various scenarios demonstrated the tradeoffs involved in re-routing and the possibility of unintended consequences of mandatory re-routing.[101] For example, a "Least Population" scenario reduced the number of people at risk, but did so with a route about twice as long in distance and time. Thus, although the population exposed in case of an accident might be diminished, the probability of an accident occurring was evidently worse. Since overall risk depends on both the probability of a release and the probable consequences of a release, the effect of such a -routing strategy on overall risk may be, at best, ambiguous.

Another rerouting analysis, conducted by Glickman, Erkut, and Zschocke, concluded however that in some cases, risk could be reduced without substantially increasing route length of shipments.[102] The authors studied alternate routes for a random selection of origin-destination (O-D) pairs, and assessed the expected number of residents exposed to the impacts of a HAZMAT release from an accident.[103] Some O-D pairs, such as the Birmingham-Providence route, offered an opportunity for risk reduction without increasing route length. Others did not. On the New York-Charlotte route, for example, an alternate route resulted in a risk reduction of 91 percent, but at the cost of a 25 percent increase in distance. The results of the study suggest that rerouting opportunities may indeed exist, but must be studied on a case-by-case basis.

The railroad industry has undertaken several TIH routing initiatives. For example, specified "key trains" carrying hazardous materials must travel on routes that are inspected at least twice per year.[104] Any track used for meeting and passing "key trains" is required to be at least Class 2.[105] Railroads prefer to route trains with TIH tank cars on

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[101] Han, Chin, Hwang, and Peterson, "A Tool for Railroad HAZMAT Routing."

[102] T. Glickman, Erkut, E., and Zschocke, M.S., "The cost and risk impacts of rerouting railroad shipments of hazardous materials." *Accident Analysis and Prevention*, Vol. 35, Issue 5, September 2007, pp. 1015-1025.

[103] Number of residents exposed was calculated as the product of the accident rate, link length, conditional release probability, impact area, and population density.

[104] AAR Circular OT-55-I. A "key train" is defined as having: "five tank car loads of Poison or Toxic Inhalation Hazard (PIH or TIH) (Hazard Zone A, B, C, or D) or anhydrous ammonia, or; 20 car loads or intermodal portable tank loads of a combination of PIH or TIH (Hazard Zone A, B, C or D), anhydrous ammonia, flammable gas, Class 1.1 or 1.2 explosives, and environmentally sensitive chemicals, or; one or more car loads of Spent Nuclear Fuel (SNF), High Level Radioactive Waste (HLRW)."

[105] The FRA classifies track based on safety in classes 1–9. The higher the class number, the higher quality the track and the faster trains are allowed to run on that track. Most freight operates on class 4 track or lower; no freight operates on tracks rated higher than class 5.

higher-quality track with better signaling systems, because this reduces risk. The dominant routing priority, however, is operational efficiency, generally determined by the shortest route. Railroads may be reluctant to shift TIH traffic away from the shortest route because such changes create both operational challenges and higher costs.

New federal regulations have signaled an increased government attention to routing. In general, the DOT has opted for a flexible approach that allows railroads considerable freedom in selecting TIH shipment routes. In a rule issued November 26, 2008, DOT explicitly declined to ban TIH movement through urban areas, acknowledging that such mandatory re-routing could potentially increase risks.[106] Instead, DOT emphasized mandatory route analyses. The new rule requires rail carriers to compile annual data on movements of explosives, TIH, and radioactive materials.[107] They must then use these data in a comprehensive assessment of safety and security risks for each route on which hazardous materials are transported, as well as possible alternate routes.[108] The rule directs that railroads use 27 specified factors as the basis for their analyses.[109] These factors include volume of HAZMAT transported, trip length for route, track type, class, and maintenance schedule, single vs. double track, proximity to iconic targets, presence of passenger traffic along route, and past incidents.[110] The rule directs that for each primary route currently used, "commercially practicable" alternatives must be identified and analyzed.[111] A practicable route is defined as "one that may be utilized by the railroad within the limits of the railroad's particular operating constraints and, further, is economically viable given the economics of the commodity, route, and customer relationship."[112] If a change in route would considerably raise costs, the rail carrier is to

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[106] DoT, PHMSA, 49 CFR Parts 172, 174 and 209, "Hazardous Materials: Enhancing Rail Transportation Safety and Security for Hazardous Materials Shipments; Railroad Safety Enforcement Procedures; Enforcement, Appeal and Hearing Procedures for Rail Routing Decisions; Final Rules." November 26, 2008. Hereafter referred to as PHMSA, Rail Routing Final Rule, November 2008.

[107] PHMSA, Rail Routing Final Rule, November 2008.

[108] Note that the regulation appears to focus more on accident risk than on the possibility of terrorism, since a targeted terrorist act would be designed to cause maximum casualties in an urban area; routing might therefore be expected to have a greater impact on reduction of risk from terrorism.

[109] These factors are specified in Appendix D to 49 CFR Part 172.

[110] Note, however, that the volume of population exposed along a route varies with time of day: at night, with a few exceptions such as nighttime athletic events, the majority of urban populations are already "sheltering in place" at nighttime, which is a common protection strategy for a public exposed to a TIH gas.

[111] PHMSA, Rail Routing Final Rule, November 2008, 72186.

[112] For definition, see Interim Final Rule of April 2008: DoT, PHMSA, 49 CFR Parts 172, 174 and 209, "Hazardous Materials: Enhancing Rail Transportation Safety and Security for Hazardous Materials

document the supporting data for such a conclusion. Carriers must consider the use of interchange arrangements. Based on the route analyses, carriers must select routes for HAZMAT that pose the least risk, balancing all relevant factors.

### *Chain of Custody*

In a complex supply chain, TIH products are passed from producer to railroad carrier to end-user or consumer. The railroad carrier may switch the product from one train to another or to a different rail carrier (referred to as interchange). These handoffs create vulnerabilities: unattended tank cars could be attacked; accidental leaks might not be immediately detected.

Because of these potential vulnerabilities, securing the TIH chain of custody was a focus in a TSA rule on Rail Transportation Security in November 2008.[113] The new regulations ordered shippers and carriers to undertake physical inspections to check for signs of tampering and to require documentation of all transfers. In high-threat urban areas (HTUAs) designated by the TSA, delivered cars must be kept within secure areas. The regulation specified the authority of TSA officials to inspect facilities and records relevant to rail security. Railroads, shippers, and receivers must designate rail security coordinators to serve as the primary contact with TSA, to coordinate security activities, and to report any incidents or concerns. Time limits are set within which rail carriers must provide TIH tank-car locations and shipping information to TSA.

Railroad companies instituted new measures to comply with these new documentation and control requirements for TIH rail cars. For example, Union Pacific notified customers that billing information for tank cars must be in UP's system before cars could be accepted by UP employees.[114] CSX notified customers that they would be responsible for designating secure areas at their shipping and receiving facilities.[115] CSX specified that in

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Shipments; Railroad Safety Enforcement Procedures; Interim Final Rule and Proposed Rule." April 16, 2008, p. 20760. Under the Final Rule of November 2008, route selection procedures were to be implemented by September 1, 2009, if six months of data were analyzed, or by March 31, 2010, if data for all of 2008 were analyzed.

[113] Department of Homeland Security, Transportation Security Administration, 48 CFR Parts 1520 and 1580, "Rail Transportation Security; Final Rule" November 26, 2008.

[114] Union Pacific, "Chemical Transportation Safety Update," April 1, 2008. <http://www.uprr.com/she/cts/prevent.shtml>

[115] CSX, Letter to HAZMAT Shippers and Receivers, December 19, 2008. <http://www.csx.com/share/customers/ch/docs/TSARegsLetter-REF24822.pdf>

HTUAs, consignees must have personnel present for hand-offs and must document all transfers.

### *Positive Train Control*

Positive Train Control (PTC) is a collection of systems designed to increase railroad safety by overriding the engineer's control of the train in dangerous situations and automatically stopping the train. The American Association of Railroads describes the purpose of PTC as "systems designed to help prevent collisions among two or more trains, to enforce speed limits and to protect employees engaged in track maintenance."[116] A PTC system uses sensors on the locomotive and along the tracks, and then makes calculations involving the train composition (or "consist") and the terrain over which the track runs to determine when and whether to stop the train.[117]

Similar collision-avoidance train protection or control systems are already in use around the world, especially in high-speed passenger operations. However, nowhere in the world is such a system in place on a network comparable in extent and complexity to the North American rail network: its freight volumes exceed those of any other rail network in the world. Recognizing the potential safety benefits, however, Class I U.S. freight railroads (the largest by operating revenues as defined by the FRA) have been developing and testing PTC prototype systems, especially since the early 1990s.[118] In the U.S. Northeast Corridor between Washington DC and Boston, Amtrak uses a version of positive train control.[119] However, the high cost of implementing such a system over the entire U.S. rail network, combined with the technical challenges, have delayed PTC implementation in the United States.

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[116] AAR, "Positive Train Control: Frequently Asked Questions," <www.aar.org/Initiatives/PositiveTrainControl/PTC_FAQ.aspx>.

[117] Positive Train Control could be complemented by electronically-controlled pneumatic (ECP) brakes, which are simultaneously activated along the entire length of the train by an electric signal. This would allow the train to stop much faster: between 40 percent and 60 percent more quickly for a long train. ECP brake systems are also considered to be more reliable and less subject to failure. However ECP brakes are incompatible with conventional brakes; an FRA official has estimated that it would cost around $6 billion to retrofit the entire North American freight car fleet for ECP brake operations. See U.S. DOT, 49 CFR Part 232, "Electronically Controlled Pneumatic Brake Systems; Final Rule," October 16, 2008, p. 61513.

[118] Peter A. Hansen, "6 high-tech advances," *Trains*, November 2008, p. 29.

[119] See description of ACSES (Advanced Civil Speed Enforcement System), the Positive Train Control system installed on Amtrak's Northeast corridor, at <www.alstomsignalingsolutions.com/OurProducts/PositiveTrainControl/ACSES/>.

The recent catalyst for PTC was the collision of a Metrolink commuter train with a Union Pacific freight train on September 12, 2008, in Los Angeles, California, which resulted in 25 deaths and over 130 injured. The accident appears to have been caused by the Metrolink engineer's failure to respond to a stop signal, resulting in collision with the incoming freight train which had not yet entered a siding to let the commuter train pass by.[120] This accident prompted legislation that was signed into law on October 16, 2008.[121] The Rail Safety Improvement Act of 2008 (RSIA) required all Class I railroads (the largest) and all intercity passenger and commuter railroads to implement a PTC system by December 31, 2015, on main line track carrying either passengers or TIH materials.[122]

The implementation of PTC in the United States involves significant practical challenges. First, effective PTC requires interoperability among all major railroads, since locomotives from one railroad often operate over the tracks of another railroad. The four U.S. Class I freight railroads promptly agreed on interoperability standards in October 2008.[123] Second, PTC is not an "off-the-shelf system": significant components of the technology must be designed, tested, and adapted for the specific operating environments of the rail lines on which they are installed. The final major obstacle is cost, including a large investment in new technology. The FRA estimated that industry-wide costs might range from \$2.3 to \$5 billion,[124] with most of this cost borne by the private Class I railroads.

While PTC will not eliminate rail accidents, it should represent a safety improvement that could help reduce the risk of all rail accidents, including those involving TIH.

### *Hours of Service Regulations*

TIH accidents at Graniteville and Macdona raised questions about the hours-of-service regulations that govern rail labor. At Graniteville, a crew running up against a time limit

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[120] Jennifer Steinhauer and Michael Cieply, "Rail Line Says Train Ran Signal; Death Toll at 25," *New York Times*, September 13, 2008, <www.nytimes.com/2008/09/14/us/14crash.html>.

[121] Rail Safety Improvement Act of 2008 (RSIA), full text and bill summary, <www.govtrack.us/congress/bill.xpd?bill=h110-2095>.

[122] Main line track is track over which 5,000,000 gross tons or more of annual traffic is transported. These requirements are defined in the legislation and are subject to further specification by the FRA.

[123] AAR press release, "Four Biggest U.S. Railroads Committed To PTC Interoperability," <www.aar.org/Initiatives/PositiveTrainControl/PTC_Interop/PTC_Interop1.aspx>. The four largest U.S. railroads are: Union Pacific, Burlington Northern Santa Fe, Norfolk Southern Corporation, and CSX.

[124] AAR, "Positive Train Control: Frequently Asked Questions."

failed to perform its duties adequately, creating the conditions that led to the accident. At Macdona, the NTSB concluded, fatigue impaired a crew's ability to operate its train safely, and the crew missed stop signals, which led to the collision. The circumstances were very different, but both demonstrate the importance of designing hours-of-service regulations that create the right incentives for safety. Hours of service rules are the product of lengthy negotiations between rail management and labor, and are subject to stringent regulation by the government.[125]

Hours-of-service regulations were among the main focuses of the Rail Safety Improvement Act (RSIA) of 2008. According to the new requirements, an employee cannot be required to be on duty:

1. Where the employee has spent in any calendar month a total of 276 hours on duty ... or in another mandatory service for the carrier;
2. for more than 12 consecutive hours; or
3. unless the employee has had at least 10 consecutive hours off duty during the previous 24 hours.[126]

An employee may not be required to remain or go on duty without specific regular periods of extended rest at his or her home terminal. The employee may not spend more than 15 hours on duty and waiting for transportation, except in case of an accident or equipment failure. Hours of service regulations are also implemented for signal employees, contractors, and subcontractors.[127]

### *Tank Car Position in Consist*

Train cars in an accident are subjected to complex and dynamic forces, which are affected by a car's position in relation to the point of impact, collision, or derailment. It would clearly be desirable to position cargoes that have the highest potential danger at the point where crash forces are weakest, but there is no consensus over what the safest position in a train consist is for hazardous materials.

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[125] The original Hours of Service Act was enacted by Congress in 1907 and has been modified many times.

[126] "H.R. 2095: Rail Safety Improvement Act of 2008 — Congressional Research Service Summary," <www.govtrack.us/congress/bill.xpd?bill=h110-2095&tab=summary>.

[127] Railroads and their employees are allowed to submit alternate hours-of-service regimes to the FRA for approval.

The NTSB has argued that TIH tank cars should be positioned at the rear of trains, based on a 1992 FRA report, "Hazardous Materials Car Placement in a Train Consist," which concluded that the rear quarter of the train had a lower probability of damage in an accident.[128] The NTSB accident report on Graniteville concluded that, "Had the chlorine cars been placed behind the other loaded cars in the train, the reduction in the trailing tonnage would have reduced the impact forces on the tank cars."[129]

The railroads, however, do not accept the argument that the rear quarter of the train is safer. They argue that regulations on placement of TIH cars within the consist would have the effect of increasing the amount of train handling and car coupling and decoupling, which present risk. The railroads emphasize procedures that minimize TIH tank car handling. Given the lack of agreement, there is little momentum for activity by regulators on this front.

### *Emergency Response*

The consequences of accidents or of deliberate attacks involving shipments of TIH materials depend in part on the effectiveness of efforts by first responders such as emergency medical services (EMS), fire, police and others local officials, as well as railroad personnel on the scene. A well informed, adequately equipped, and effectively executed response can limit the scope of property damage and the loss of life. Response strategies might include containing exposure through patching, flooding the area with water, leading evacuation efforts, or encouraging shelter in place. The presence of an effective response capacity might also deter terrorist attacks, by making it clear that the amount of harm that could be achieved is limited.[130] In some instances, ineffective emergency response can actually make things worse; calling for sheltering in place or evacuation when the opposite strategy would be the best course of action can needlessly place populations at risk. Developing capacities for effective emergency response to TIH release is a form of resilience and risk mitigation that could help to reduce the overall scope of the externality associated with the transportation of TIH materials.

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[128] R.E. Thompson, E. R. Zamejc, and D. R. Ahlbeck, *Hazardous Materials Car Placement in a Train Consist*, Vol. 1: *Review and Analysis*, Report DOT/FRA/ORD/18.I (Washington, D.C.: Federal Railroad Administration, U.S. DOT, 1992).

[129] NTSB Report—Graniteville.

[130] Research and Special Projects Administration, Office of Hazardous Materials Safety, Department of Transportation, and John A. Volpe National Transportation System Center, *The Role of Hazardous Materials Placards in Transportation Safety and Security* (2003), p. iii.

The challenges of responding to a TIH incident have been on the public agenda since at least the early 1900s. A number of serious rail accidents involving the transportation of dangerous materials during this period spurred wide-spread concern and led the railways to create, in 1907, the bureau of explosives (BOE); federal controls were established a year later under the authority of the Interstate Commerce Commission (ICC).[131] Since the terrorist attacks of September 11, 2001, railroads, chemical manufacturers, and government renewed efforts to help ensure that local communities can quickly and effectively respond to a TIH incident. These efforts have expanded the abilities of emergency responders and helped to reduce the risk associated with the transportation of TIH materials, but there are still areas where public policy could do more to improve emergency response.

The transportation of shipments across a freight rail network comprising 140,000 miles of track creates difficult challenges for emergency response and planning.[132] TIH shipments travel across jurisdictions throughout the nation, along routes that are not usually specified ahead of time.[133] An unanticipated release could happen in many unexpected locations along the transportation route. Even communities without chemical facilities must be prepared to respond to a TIH incident. Thus, while rail security and safety is a national issue, initial response is a local activity.

The federal government, the chemical industry, and the railroads support local first responders through regulations, support for training, funding, and quick-response networks. Generally, federal law preempts local and state statutes governing the transportation of hazardous materials.[134] Federal law directs levels of training and response planning at the local and state level. It also requires clear markings on shipments of hazardous materials.[135] Federal legislation in 1986 directed the creation of local emergency planning committees (LEPCs) and state emergency planning committees (SEPCs) to develop plans and provide coordination for response to emergencies.[136]

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[131] Transportation Research Board, *Cooperative Research for Hazardous Materials Transportation: Defining the Need, Converging on Solutions* (Washington, D.C.: National Academies Press, 2005), p. 24.

[132] Transportation Security Administration, *Freight Rail Modal Annex*, 2007, <www.tsa.gov/assets/pdf/modal_annex_freight_rail.pdf>, p. 2.

[133] Association of American Railroads, "HAZMAT Transport by Rail," 2008 p. 4.

[134] Transportation Research Board, *Cooperative Research for Hazardous Materials Transportation*, p. 34.

[135] Marking hazardous shipments could increase the vulnerability to intentional disruptions or acts of terrorism, an issue discussed below.

[136] Title III of the Superfund Amendment and Reauthorization Act of 1986 (SARA), also known as the Emergency Planning and Community Right-to-Know Act. See Linda-Jo Schierow, "The Emergency

Labor Department regulations in conjunction with professional organization guidelines spell out obligations of first responders and mandate minimum levels of training.[137] Within the Department of Labor, Occupational Safety and Health Administration (OSHA) regulations define the minimum levels of training for first responders that may deal with hazardous materials. Recently, the National Fire Protection Organization (NFPA), a professional organization representing a significant portion of the first responder community, revised its guidelines interpreting the applicability of OSHA regulations in order to incorporate HAZMAT/WMD planning.[138] This revision responded to the suggestion that current interpretations of the baseline levels of competency were set too low to address the possible threat of terrorism and did not assure adequate first response capabilities.[139] NFPA guidelines now recommend that all fire, EMS, and other individuals who may be called to respond to a toxic incident are trained at the "operations" level, as defined by OSHA regulations. Previously, NFPA guidelines recommended that first responders be trained at the more basic "awareness" level in order to satisfy OSHA regulations. This revision in the interpretation of the applicability of OSHA regulations is a potentially significant change that supports a higher level of training and readiness for all first responders.[140]

The federal government, and the chemical and railroad industries, support and provide training programs for first responders and their own personnel.[141] Examples include CHEMTREC, the Chemical Transportation Emergency Center, which is supported and founded by the American Chemistry Council; the Transportation Technology Center (TTC), which is operated by the Association of American Railroads; and TRANSCAER (Transportation Community Awareness and Emergency Response), which is supported by the chemical and transportation industries and the emergency response community.

A variety of federal grants and programs help offset some of the costs of specialized training and equipment devoted to hazardous materials. Since 1990, DOT's Hazardous

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Planning and Community Right-to-Know Act (EPCRA): A Summary," Congressional Research Service (CRS) Report RL32683, 2007.

[137] See 29 CFR 1910.120(q)(6); National Fire Protection Association (NFPA), *NFPA 472: Standard for Competence of Responders to Hazardous Materials/Weapons of Mass Destruction Incidents*, 2008.

[138] NFPA 472.

[139] See Steven Bell, "Current Issues in Transportation of Hazardous Materials," Hearing before the U.S. House of Representatives, Subcommittee on Railroads of the Committee on Transportation and Infrastructure, June 13 2006.

[140] See Gregory Noll, "NFPA 472," *NFPA Journal*, March/April 2008.

[141] See <www.phmsa.dot.gov/HAZMAT>.

Materials Emergency Preparedness Grant Program provided $182 million in HMEP grants to states and territories for the development of response plans, training, and purchase of specialized equipment.[142] Additionally, FEMA distributed over $2. 4 billion through the Assistance to Firefighters Grant (AFG) program since the inception of the program in 2001.[143] These grants are offered annually to support firefighters and EMS first-responder activities, with highest priority on those activities that support response to chemical, biological, radiological, nuclear, and explosive (CBRNE) threats.[144] Yet despite ongoing support, as of April 2008 only 16.4 percent of U.S. fire departments had specialized HAZMAT teams.[145]

DOT regulations also support first responders. DOT regulations[146] require that shippers of hazardous materials provide accompanying information (in the form of both external placards and markings, as well as on shipping papers) about the type of material transported, the quantity, and a 24-hour emergency contact number that connects to a person informed about the hazardous material being transported and appropriate emergency response measures.[147] These regulations are critical to first responders. First responders are often initially alerted to the presence of a dangerous material through color-coded placards or other labels that are required by DOT regulations. Additionally, 24-hour hotlines operated by CHEMTREC and TRANSCAER supply first responders with emergency contact information and technical support. At the federal level, the National Response Center (NRC) coordinates between federal entities in the event of an accident involving hazardous materials and supplies support to on-site authorities.[148] The

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[142] HMEP grants are paid for by fees collected from shippers and carriers of hazardous materials. PHMSA, Hazardous Materials Emergency Preparedness (HMEP) Grants Program Fact Sheet.

[143] DHS. "America's Firefighters to Receive $485 Million in Grants." October 6, 2006. <http://firegrantsupport.com/docs/media06_061006.pdf>.

[144] Department of Homeland Security, Notice of Guidelines, *Federal Register*, Vol. 73, No. 50, March 13, 2008, p. 13555.

[145] See U.S. Fire Administration website, <www.usfa.dhs.gov/applications/census/summary.cfm#table1>. See also National Research Council, *Terrorism and the Chemical Infrastructure*, p. 53.

[146] 49 CFR 172.

[147] Transportation Research Board, *Cooperative Research for Hazardous Materials Transportation*, pp. 67–68.

[148] The National Response Center (NRC) is the federal point of contact for reporting oil, chemical, radiological, biological, and etiological discharges. The NRC coordinates response actives between multiple federal entities and on-scene authorities. <www.nrc.uscg.mil/>.

chemical industry, through CHEMNET, and many railroads also field rapid-response teams to support on-site activities by responders at the local, state, and national levels.[149]

The efforts just described largely focus on the unique demands of hazardous material incidents, but effective emergency response also requires more general health and safety capabilities. Neglecting the broader challenges facing this infrastructure while focusing narrowly on ways in which HAZMAT response is novel could hamper the ability of local officials to respond to a TIH release. In addition, there is a potential for reducing overall safety and security if steps taken to counter the threat of terrorism raise the risk of accident, or vice versa.

The threat of terrorism creates responsibilities and burdens for first responders. The re-designation of first responders at the "operations" level, for example requires a greater commitment to specialized training and equipment.[150] This creates new burdens at a time when funding for many basic fire and EMS services is lacking. Devoting resources to preparing for low-probability events such as TIH incidents and terrorism diverts resources from challenges that may be more pressing. Federal programs and industry support offset some of these costs, but significant budgetary constraints at the local level mean that preparations for unlikely scenarios may be difficult to sustain and justify when support the general operations of first responders is lacking or inadequate.[151] Without support for general operations, first responders will be under pressure to divert funds that are earmarked for specialized requirements, and to neglect those requirements. Providing general support for first responders, then, is an important component of addressing the unique challenges of transporting TIH materials.

Responding to the unexpected and fast-moving challenge of a TIH release involves special demands. A key challenge for first responders is to determine whether and how to direct nearby residents to shelter in place or to evacuate.[152] Determining which option is best requires expertise and simulation tools to synthesize a raft of data, including

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[149] Transportation Research Board, *Cooperative Research for Hazardous Materials Transportation*, p. 69.

[150] Equipment may be relatively cheap and simple, such as a drum handling tool, or expensive and sophisticated, such as advanced robotics. USFA, *Hazardous Materials Response Technology Assessment*. HAZMAT imposes specialized response conditions; for example, sometimes response must be delayed so that environmental conditions can be assessed remotely before first responders arrive on the scene. Bell, "Current Issues in Transportation of Hazardous Materials."

[151] Budgetary constraints are a perennial challenge for local fire services, sometimes forcing cuts or reductions in basic services. USFA, "Introduction," *Funding Alternatives for Fire and Emergency Services*. 2000, <www.usfa.dhs.gov/downloads/pdf/publications/fa-141.pdf>.

[152] National Institute for Chemical Studies, "Sheltering in Place as a Public Protective Action," 2001.

information about the material released, current meteorological conditions, and the topography of the exposed area. Advances in dispersion modeling, such as recent work undertaken by the U.S. Naval Research Laboratory, suggest that it may soon become possible to provide emergency responders with near-real-time predictions for the spread of a release of TIH through a complex urban environment.[153] The availability of such information could help emergency responders assess the rapidly evolving conditions of a TIH incident and advise the public accordingly. Such services might also speed up response time by providing essential meteorological data much faster.

Such technologies, to be effective, require "dual-use" tools applicable to a much broader range of circumstances, including effective public channels of communication and an extensive and continuing program of public education. Working and accessible emergency communication systems, including reverse 9-1-1 systems, sirens such as those used in tornado warning and civil defense, and the federal Emergency Alert System (EAS) are indispensable to ensuring that essential directions are received by the public. The Emergency Alert System, which relies on broadcasters and cable outlets, among others, to distribute instructions, failed during the derailment and ammonia release in Minot, ND in 2002, which hampered response efforts.[154] Developing and implementing sophisticated real-time simulation technologies is inadequate without devoting resources to maintaining other tools, such as channels of communication, and assuring that hospital staffs and facilities can handle the surge in patients and "worried well" that may result in the wake of TIH incident.[155]

The general challenges of emergency response thus intersect in many ways with the specific needs of HAZMAT response. Efforts to create an emergency response capacity for the unique features of a TIH incident also require a robust general response infrastructure.

In addition to new simulation tools, pre-notification and educational efforts directed toward at-risk populations can also reduce response times.[156] Pre-notification can reduce

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[153] Describing recent advances in simulation technology and how it can be usefully applied to unexpected releases of TIH is Boris, "The Threat of Chemical and Biological Terrorism."

[154] Jack Shafer, "What Really Happened in Minot, N.D.?" *Slate*, January 10, 2007 <www.slate.com/id/2157395/>.

[155] National Research Council, Committee on Science and Technology for Countering Terrorism, *Making the Nation Safer: The Role of Science and Technology in Countering Terrorism* (Washington, DC: National Academies Press, 2002), pp. 127-131.

[156] On the importance of pre-notification and education in the context of a large-scale release within a densely populated area, Transportation Security Administration, "Proceedings of the May 28, 2008

the lag between initial notification and response through the coordination of TIH information with local emergency services. Local emergency responders and 9-1-1 services should be knowledgeable about the frequent types and locations of TIH shipments in their community before an incident occurs.[157] They should also have quick access to specific information concerning the presence of TIH shipments within a community that can be accessed as fragmentary reports are first coming into 9-1-1 operators. Doing so will allow emergency responders to quickly identify a possible TIH incident before arriving on scene and shorten the window for identifying which TIH material has been released.[158] During a release in a densely packed area, however, those in the immediate vicinity will have to take action before professional responders arrive on the scene. Educational outreach efforts targeting communities near chemical plants and rail yards that serve as hubs for TIH material describing how to properly shelter in place can be instrumental in mitigating the damage from a release.[159]

Wide distribution of information concerning the movement of TIH materials supports safety measures that are designed to limit the number of accidents and ensure effective response. Yet there are concerns that the availability of such data potentially undermines security, by providing terrorists with information that could be used to launch an attack. The tension between safety and security is evident in recent debates concerning the appropriate identification of hazardous materials.

Placards to identify hazardous materials are communication tools that are easy to understand and are recognizable by the first responders and workers that handle over 1.2 million hazardous materials movements daily.[160] However, the same qualities that makes such placards useful — their simplicity and accessibility to observers — may also facilitate attacks, by assisting terrorists in identifying TIH tank cars.[161] DOT and DHS recently examined alternative measures, such as radio frequency identification tags (RFIT), or operational alternatives such as armed escorts. However, the high cost of new

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Chicago-Area TIH Materials Emergency Response & Preparedness Roundtable," Version 1.1, Sept. 14, 2009.

[157] Ibid.

[158] Ibid.

[159] Ibid.

[160] DOT and Volpe Center, *The Role of Hazardous Materials Placards*, p. 8.

[161] A DOT study concluded that placards would not supply enough information to terrorists to facilitate a significant attack. Ibid. p. iii.

investments in technology and training were judged to offer only marginal benefits, and these alternatives were dismissed.[162]

### *Product Substitution and Supply Chain Management: "Inherently Safer Technologies"*

The most desirable solution in preventing chemical releases is to reduce or eliminate the hazard where possible, not to control it. This can be achieved by modifying processes where possible to minimize the amount of hazardous material used, replace a hazardous substance with a less hazardous substitute, or minimize transportation by co-locating production and use.[163] Product substitution and supply chain reorganization address the risk associated with the use and transportation of toxic chemicals at the source. These strategies are often grouped together under the rubric of "inherently safer technologies" (ISTs).[164] However, product substitution and supply chain reorganization are contentious issues that present significant political, economic, and technical barriers to implementation.

There have been many recent calls on the federal government to support the development and adoption of ISTs. In addition to the recommendation of the National Research Council, environmental groups such as Greenpeace and the Environmental Defense Fund have publicly declared their support for an active federal role mandating the use of ISTs in certain cases.[165] Security experts note that there is a need for government to provide incentives to encourage businesses to develop and adopt ISTs that would otherwise be economically unfeasible.[166] The railroad industry supports the promotion of ISTs as a

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162 Ibid. See also "Department of Homeland Security Announces Support for Rail HAZMAT Placards." April 8, 2005, <www.dhs.gov/xnews/releases/press_release_0655.shtm>.

163 National Research Council, *Terrorism and the Chemical Infrastructure*, p. 106.

164 "Inherently safer technologies" may include a broad range of strategies, including product substitution and supply chain redesign. Senate Bill 1602, introduced in the 107th Congress, for example, defined ISTs broadly to include processes that limit or reduce the use, storage, and transportation of toxic chemicals through process redesign and simplification, product reformulation, or input substitution.

165 Rick Hind (Greenpeace), Testimony before Committee on Homeland Security, Subcommittee on Transportation Security and Infrastructure Protection, December 12, 2007. Carol Adress (Environmental Defense Fund), Testimony before Senate Committee on Homeland Security and Government Affairs, July 13, 2007.

166 Report 109-332, "Report to Accompany Chemical Facility Anti-Terrorism Act (S. 2145)," U.S. Senate Committee on Homeland Security and Governmental Affairs, 2006, p. 9.

way of solving its problems with transporting dangerous TIH materials.[167] At the Congressional level, proposed legislation would provide some support for ISTs, ranging from making their use mandatory, to requiring review of the possibilities of their use.[168] At the state and local level, a number of efforts have been undertaken to support the use of ISTs.[169]

However, the chemical industry opposes legislation that would lead to greater implementation of ISTs.[170] Chemical industry critics object to any federal role in promoting ISTs to achieve safety and security.[171] A related objection questions whether regulations should be considered within the sphere of environmental law or of national security.[172] John Chamberlin, Corporate Security Manager, Asset Protection for Shell and a representative of the American Petroleum Institute, testified that he was: "strongly oppose[d] to any environmental mandates for inherently safer technology pursued under the guise of security."[173] This argument fails to acknowledge that the government has responsibility both for national security as a military matter, and for homeland security, assuring the well-being of the public.

The success of regulatory support for "inherently safer technologies" is uncertain and remains mired in ongoing disputes between advocates and opponents of ISTs.[174] However, the argument about the merits of specific ISTs is separate from question of

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167 American Association of Railroads, Statement for the Record to the U.S. House of Representatives Committee on Homeland Security, Subcommittee on Transportation Security and Infrastructure Protection, December 12, 2007.

168 Senate Bill 1602, the Chemical Security Act of 2001, and Senate Bill 2486, the Chemical Safety and Security Act of 2006, both supported the adoption of ISTs.

169 Dana Shea and Todd Tatelman, "Chemical Facility Security: Regulation and Issues for Congress," Congressional Research Service, Report RL 33847, 2008, p. 8.

170 Jacob Schlesinger and Thaddeus Herrick, "Delayed Reaction: Chemical Manufacturers Elude Crackdown on Toxic Materials," *Wall Street Journal,* May 21, 2003; Shea and Tatelman, "Chemical Facility Security."

171 Report 109-332, "Report to Accompany Chemical Facility Anti-Terrorism Act."

172 Paul Rosenzweig, "The Chemical Security Act: Using Terrorism as an Excuse to Criminalize Productive Economic Activity," Heritage Foundation Executive Memorandum no. 833, September 12, 2002, <http://www.heritage.org/Research/HomelandSecurity/em833.cfm>.

173 Report 109-332, "Report to Accompany Chemical Facility Anti-Terrorism Act," p. 16.

174 Bruce Alpert, "Chemical Security Bill Wins Nod from House: Industry May Press Battle in Senate," *The Times-Picayune.* November 7, 2009, < http://www.nola.com/news/t-p/capital/index.ssf?/base/news-7/1257576020228640.xml&coll=1>.

what kinds of policies should be established that will induce firms to use them. All things begin equal, it is usually preferable to establish incentives to develop and use ISTs rather than creating a mandate to use specific technologies, because with incentives, research investments may discover ISTs that are both more effective and lower in cost than those now in use.

Critics and proponents of federal support for ISTs agree that, at present, significant technological and economic barriers prevent the large-scale elimination of the use of toxic chemicals. In some cases, alternatives simply do not yet exist, while in other instances, the costs of substitution are judged to be prohibitive.[175] For example, there are a number of alternatives to the use of chlorine gas in water treatment, such as processes that use ultraviolet light and sodium hypochlorite. However, as the chemical industry points out, there are far fewer alternatives to the use of chlorine in the production of plastics.[176]

The cases of chlorine and ammonia illustrate the possibilities and limitations of substitution and supply chain reorganization. The two chemicals present different challenges based on the nature of the products and the industries within which each is used, the alternatives available, and the costs of conversion. The case of chlorine reveals some conditions under which substitution or changes in the supply chain are both feasible and desirable. For example, swimming pools can be equipped with chlorine generators that electrify salt into chlorine, eliminating the need for chemicals that are typically manufactured regionally from long haul shipments of chlorine gas. Although the volumes involved may be relatively small, this kind of initiative illustrates the potential for incremental steps to reduce transportation of TIH. Usage and distribution of ammonia, by contrast, illustrates some of the challenges, as detailed below.

One of the most common uses for chlorine gas has been in purification of drinking water and wastewater.[177] In comparison with other industrial processes using chlorine gas, purification offers significant scope for potential substitution. Over the past decade, some

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[175] National Research Council, *Terrorism and the Chemical Infrastructure*, p. 7.

[176] Benjamin Brodsky, "Industrial Chemicals as Weapons: Chlorine," Nuclear Threat Initiative Issue Brief, 2007, < http://www.nti.org/e_research/e3_89.html>. See, however, "Clorox to Halt Use of Chlorine at Bleach Production Sites."

[177] Since 1999, all facilities using over 2,500 lbs of chlorine are subject to the Environmental Protection Agency's Risk Management Program (RMP) guidelines. The 2002 Bioterrorism Preparedness Act imposed additional security and safety obligations on all drinking water facilities (but not wastewater), requiring that all drinking water facilities serving over 3,300 people must prepare vulnerability assessments.

water facilities have begun to employ less-toxic methods of operation.[178] Sodium hypochlorite (NaOCl, a form of liquid bleach), ultraviolet light, ozone, and bleach generated on-site are some of the alternatives to chlorine gas.[179] Since 1999, at least 114 wastewater plants and 93 drinking water facilities have adopted less acutely toxic chemicals.[180] A 2006 survey of over 200 of the nation's largest wastewater utilities, serving roughly 25 percent of the U.S. population, found that less than half currently use chlorine gas, and an additional 10 percent plan to convert to a less toxic process in the near term.[181] A survey of facilities that recently converted from chlorine to an alternative found that initial conversion costs ranged from slightly over $600,000 to $13 million, depending on what new form of disinfection is used, the size of the facility, and building costs.[182] Liquid bleach generally costs the least, in terms of conversion and annual supply costs, compared to other alternate forms of disinfection. Switching to an alternative method in some instances actually projected to be cost-neutral or even produced a net savings in the long term.[183] The regulatory and reporting costs associated with handling large amounts of chlorine gas, for example, can be eliminated by switching to an inherently safer technology. Nonetheless, over 2,800 water facilities still use quantities of toxic chemicals that require reporting under the risk-management planning requirements of the Clean Air Act.[184]

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[178] Claudia Copeland, "Terrorism and Security Issues Facing the Water Infrastructure Sector," CRS Report RL32189, 2008, p. 5.

[179] Orum, *Preventing Toxic Terrorism*, pp. 10–11; Government Accountability Office (GAO), "Securing Wastewater Facilities: Costs of Vulnerability Assessments, Risk Management Plans, and Alternative Disinfection Methods Vary Widely," March 2007, pp. 5-6.

[180] Orum, *Preventing Toxic Terrorism*, p. 10. "Despite these improvements, approximately 1,150 wastewater facilities and 1,700 drinking water plants [still use] extremely hazardous chemicals, primarily chlorine gas." Ibid.

[181] GAO, "Securing Wastewater Facilities: Utilities Have Made Important Upgrades but Further Improvements to Key System Components May Be Limited by Costs and Other Constraints," March 2006, pp. 2-5, 15-16.

[182] GAO, "Securing Wastewater Facilities: Costs of Vulnerability Assessments, Risk Management Plans. and Alternative Disinfection Methods Vary Widely," p. 13.

[183] Ibid.

[184] Copeland, "Terrorism and Security Issues Facing the Water Infrastructure Sector," p. 5. Any facility that stores over 2,500 lbs of chlorine gas must submit risk management plans to the EPA. GAO, "Securing Wastewater Facilities: Utilities Have Made Important Upgrades but Further Improvements to Key System Components May Be Limited by Costs and Other Constraints," March 2006, p. 9.

Anhydrous ammonia, which is used in fertilizer and other applications, presents a different set of challenges. Because there are many forms of fertilizer, there are numerous potential alternatives to direct application of anhydrous ammonia, including other nitrogen-based fertilizers, phosphorous-based fertilizers, and potassium-based fertilizers.

However there are numerous economic and logistical challenges to replacing anhydrous ammonia. It has a much higher nitrogen content than other fertilizers, so it is a more cost-effective option for farmers. Ammonia is also an input for other nitrogen-based fertilizers, such as nitrogen solutions or urea, as well as phosphate fertilizers. Agriculture industry advocates assert that, "the current level of crop production in the U.S. could not economically be sustained without the use of ammonia."[185] Anhydrous ammonia is the only commercial fertilizer that can be effectively applied to crops in the fall.[186] Thus, it is argued, any fertilizer substitutes for anhydrous ammonia would be required in greater volumes, at greater cost, and with a high impact to farmers. Substitution of ammonia in industrial processes would likely be even more complicated.[187]

If external costs due to transportation hazards are not incorporated into the price, the feasibility of substitution of other fertilizers for anhydrous ammonia will depend on trade-offs between the resulting safety improvements and the potential loss of convenience and additional costs of alternatives to ammonia. The two sides in the debate over the potential for substitutions for ammonia appear to be very far apart. A federal push to reduce ammonia consumption might only be successful if significant subsidies to alternative products are offered. It may be more efficient to focus efforts on extending the pipeline network and promoting pipeline transportation of ammonia in order to decrease shipments by rail and truck.

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[185] "Statement on Behalf of Fertilizer Institute by Joe Giesler, Terra Industries, before PHMSA and FRA, Public Meeting on Safe Transportation of Hazardous Materials to Address the Safe Transportation of Hazardous Materials in Railroad Tank Cars," p. 181.

[186] "Testimony of Robert Felgenhauer and Supplemental Written Submission on behalf of the Fertilizer Institute, Before the STB, EP 677, Common Carrier Obligation of Railroads."

[187] Giesler Statement before PHMSA and FRA.

## V. Policy Options and Assessment

TIH stakeholders have taken some important initiatives to reduce the risks of a breach of TIH safety or, to a lesser degree, a breach of security, and to minimize the negative impacts if a release does occur. However, the actions taken have generally been uncoordinated and have focused on objectives of specific stakeholders. Such an approach is likely to lead to suboptimal outcomes. For example, improved tank car design without product substitution might reduce the probability of a release if there is an accident or terrorist attack, but does not address the underlying dangers of shipping such hazardous materials. Similarly, creating a fund to pay for catastrophic damage due to a TIH release does nothing to improve safety and security of the TIH supply chain. Successfully tackling the TIH issue requires a more coordinated set of policies that address the volume of TIH moved, the safety and security with which they move, effective responses to a release, and mechanisms to limit or share liability where appropriate and to compensate victims when needed.

Such a comprehensive and coordinated response must take into account the following key factors:

- the risks to the public and to all elements of the supply chain from a TIH release;
- the importance of TIH products to the economy;
- the externalization of the costs of TIH risk;
- the distribution of interest and accountability among numerous industries, including rail, chemical, agricultural, and water treatment entities;
- the difficulties of quantifying a low-probability, high-consequence TIH event;
- the inestimable possibility of an accident or terrorist act releasing TIH material;
- the large number of variables in any prediction of damage;
- the large geographic area requiring protection;
- the variety of costs and benefits of substituting safer products;
- the cost and uncertainties involved in planning appropriate capabilities and emergency responses;

- the difficulty of coordinating approaches by a broad range of governmental regulators, each of whose responsibility is somewhat isolated (or "stovepiped") from the rest.

Approaches used to address other types of externalities provide some guidance; environmental externalities, in particular, have many close analogies to TIH. Legislative, regulatory, activist, and business interests have come together to craft many solutions to environmental problems that may delight few, but are acceptable to most, and taken together have had strong positive effects. They offer some lessons that are relevant for addressing TIH:

- All stakeholders need to be at the table; each must "give and get."
- Regulatory authority must be clear and, if not focused in a single organization, must be consistently coordinated.
- Economic incentives influence business and consumer decision making.
- Taxes, broadly defined include government levies or industry fees, can be an effective tool to internalize external costs into the price of goods and services.
- Markets can be effectively used to cap and trade external costs.
- Operating practices and technology can be used to minimize external costs.
- A well-designed set of actions can lead to successful outcomes for business and society.

Policy solutions should be guided by clearly stated principles to ensure that they are effective, cost-efficient, and acceptable. The guiding principles we propose are:

- Policy solutions should recognize the risk of TIH carriage as an externality, and should aim to incorporate external costs into the cost of TIH products and their transportation.
- There is no single solution; instead, a menu of policies aimed at reducing risk and consequences should be adopted, such as:
    - product substitution by chemical users,
    - relocation of production, to reduce the need for transportation and resulting exposure,

- improvements in rail safety, such as better tank car design, and
- operational changes in TIH transport, including routing and timing of shipments and other security measures.

- Unintended consequences should be part of the assessment of policies that appear to optimize the safety of the parties and the public while minimizing costs. For example, attempts to internalize the TIH externality through higher rail transportation prices could lead to the diversion of TIH transport to trucks and other modes that are actually less safe.

- To the extent practical, solutions should allow markets to allocate accountability equitably, effectively, and with incentives for all of the parties to invest in mitigation of consequences of accidents.

- The interests, financial and otherwise of all of the stakeholders and all elements of the supply chain — TIH chemical producers, railroads transporting TIH, producers of TIH tank cars, industrial consumers of TIH chemicals, and first-responder institutions — in the management and financing of externalities associated with TIH production, transport, and use must be taken into account when safety policies are made.

- Regulatory authority should be as clear and concentrated as possible to simplify policy creation and enforcement.

- Participation by the government is particularly necessary for assessment and mitigation of the risk of terrorist attack, because the consequences of a well-planned and executed attack, however improbable, could far exceed those of TIH accidents. The resulting financial burden would require a special role for government, because private insurance would be inadequate.[188]

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[188] Mitigation of the terrorism threat has been discussed above in each of the relevant sections: rerouting shipments, avoiding large concentrations of people potentially exposed, investments in faster, technically trained and equipped response capability, and public training sufficient to save significant numbers of lives. While most of these steps are to some degree cost-justified as protections of the public from accidental releases, for such steps to be sufficiently rigorous to prevent massive loss of life from a terrorist attack would require very large government and private investments, especially since one cannot know in advance what cities might be targeted. Using $10 million per life saved as a criterion, the analysis by Barrett shows that an effective degree of mitigation from a successful terror attack would be greater than this threshold. See Barrett, "Mathematical Modeling and Decision Analysis for Terrorism Defense."

Taking these principles into account, we recommend four approaches by which Congress and federal regulators should create incentives, funding, and mandates to address the TIH challenge:

- internalizing external costs, and creating a fund for claims;
- improving supply chain operations;
- enhancing emergency response; and
- focusing regulatory authority.

We discuss each in turn in the last part of this paper.

### *Internalize External Costs and Create a Fund for Claims*

A key obstacle to minimizing the risks of TIH products is that the external costs of risk are not included in the decision making process of the supply-chain participants. Since there are in many cases products or processes that can substitute for TIH materials, increasing the price of TIH products by incorporating the costs of risk should lead to less TIH usage. Thus, the first action recommended is that the supply chain participants should estimate the cost of risk and internalize it into the price of TIH products.[189]

For the reasons described in this paper, estimating the cost of risk is extremely challenging and potentially controversial. Nevertheless, a first approximation of the cost of risk already exists in the price of private insurance. Each supply-chain participant faces some exposure to an accidental or intentional release of TIH material. In order to protect themselves, the producers, transporters, and users may seek insurance. The cost of such insurance is high, however, because of the limited pooling opportunity for this type of risk and the potential for substantial damage payouts.[190]

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[189] The recommendations in this section address the internalization of risks from an accidental release. A more complex analytical approach would be needed to assess the risks of a terrorist attack.

[190] Because the insurance is very costly, most participants self-insure for damages up to around $25 million and then buy high-deductible insurance coverage of approximately $1 billion. Railroads report that TIH insurance with low deductibles is very costly, and protection is not available above $1 billion. Availability of coverage has decreased over the past few years, as has the number of insurance companies willing to cover freight rail. See Testimony of James Beardsley, Managing Director, National Rail Transportation Practice, Aon Risk Services, before U.S. House of Representatives Committee on Transportation and

A first step towards reflecting these costs would be to incorporate insurance costs for the entire supply chain into the freight rates. However, this approach faces an institutional barrier, in that product-specific insurance costs cannot be included in the Surface Transportation Board (STB) tests of rate reasonableness. The STB would need to modify its current rules to facilitate implementation of this concept. Internalizing the external cost of TIH risk via this insurance model would be a market-based but indirect approach.

A more comprehensive approach would require calculation of the expected costs of risk per ton-mile of TIH moved, once all required operational improvements have been included. A potentially useful quantification methodology would center on an analysis of the probability of an accident resulting in a release, and the expected costs of such an incident. Establishing these parameters is challenging, because they are sensitive to a multitude of assumptions.

The problem could be viewed as analogous to estimating the health effects of air pollution in the 1970s. Those analyses were not analytically elegant and were highly controversial, but establishment of at least a rough estimate was essential to understanding the magnitude of the external costs, mobilizing stakeholder interest in resolving the problem, and determining the allocation of resources. The same may be true for TIH. Analysis could be sponsored by a federal agency such as the FRA or PHMSA; and sensitivity tests could be used to test assumptions and specify a range of reasonableness around the external costs. The results of such an analysis could be incorporated into the cost of TIH transportation by one of the means described above (insurance, rate calculations, etc.).

Incorporation of the risk of TIH release into transportation costs might appropriately be accompanied by creation of a liability fund to pay claims in the event costs of a release exceeded insurance coverage. Otherwise, a large accident, or multiple accidents, might bankrupt one or more supply chain participants. Following the Oil Spill Liability Trust Fund (OSLTF) model, a federally-sponsored TIH liability fund could create a pool of money for damage from releases beyond insurance coverage. The OSLTF funding mechanisms (the tax on oil, cost recovery from negligent parties, and the interest earned on the fund) could serve as a model.

In contrast to the OSLTF, which is not a no-fault model, the desirability of a no-fault insurance model for TIH should be evaluated, since the possibility and extent of damage may be affected by the actions of multiple players. From the design of the tank cars to

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Infrastructure, Subcommittee on Railroads, "Current Issues in Rail Transportation of Hazardous Materials," June 13, 2006, p. 44.

their maintenance to the movement over the nation's rail system, the actions of each participant affect the overall integrity of the system. Attempts to assign fault for anything short of gross negligence could result in unproductive finger-pointing and litigation. In recent accidents, rail employee (human-factor) causes contributed to the accidental release of TIH, but often the railway may be sued even if fault apparently lies with the shipper's loading procedures, simply because the railroad company's pockets may be seen as deeper than those of other participants in the supply chain. Railroads are required to move TIH shipments under their common-carrier obligation and cannot decline to accept TIH risk. With all these factors in mind, the Price-Anderson Act, FDIC, and OSLTF models should be evaluated by policymakers to determine which elements of each model can be applied to the TIH supply chain to minimize risk.

Another model that might help minimize use of chlorine gas in water treatment is the "stranded asset recovery" model found in the electricity industry. Under this model, electric utilities were allowed to add a small surcharge to the electricity price they charged their customers to recapture the foregone value of assets sold below book value due to regulatory requirements. The same rationale could be used if water authorities, especially those in high-threat urban areas, are required to eliminate the use of chlorine gas. They could be allowed to recapture costs to convert to a substitute technology through a small "product substitution fee" added to water users' bills.[191]

Another possible model to encourage substitution of safer products for TIH materials is cap-and-trade. This approach could be applied to TIH transportation by awarding a fixed number of TIH permits for production, for use, and for transportation. Limiting the total quantity of TIH produced, consumed, and transported would create incentives for product substitution and relocation of production or use. Permits could be decreased over time to push for further replacement of TIH chemicals with less toxic alternatives. Cap-and-trade has not been applied to analogous situations, so significant analysis would be necessary to decide at what point in the supply chain to award allowances, and also whether allowances should be grouped, or instead separated by TIH commodity.

Whatever solution is ultimately created, internalizing costs and creating a fund for damages could lead to a price shock for TIH users, who have made investment and production decisions based on prices that did not include the external costs. Changing the economics in "mid-stream" raises equity issues, especially for users who made long-term investments in fixed assets such as water treatment plants and complex chemical

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[191] Some may challenge such an approach as heavy-handed, but there is ample precedent for such mandates that support the safety and welfare of the public, even in the realm of rail transportation: mandated positive train control and was largely unfunded by the government.

facilities. To address this issue, transitional phase-in could spread the external costs over a number of years. The transition could be accelerated by government-offered low interest loans or tax advantages, which would be justified by the social welfare gains of reducing the volume of TIH usage. A recent precedent for similar government conversion subsidies is the federal government's funding of television converter boxes as a result of the mandated shift to digital broadcasting. Determination of the most effective approach should be made by the DOT and enacted into law by Congress.

None of these policy options are, however, sufficient to compensate for the potential worst-case consequences of a terrorist attack on a shipment of TIH through a highly populated area. For such a situation, the government's terrorism re-insurance system (TRIA, described above) is available. TRIA might also be extended to cover particularly damaging accidents, as well, since the consequences of accidents occurring at midday in a city might approach those of a terror attack. This might mitigate some of the financial pressure on of internalizing the risk of TIH accidents into product and shipping costs.

These suggestions, targeted at internalizing the TIH externality and creating a fund for TIH release-related damages, should yield three positive outcomes. The first is to reduce the volume of TIH materials used, through encouragement of product substitution and increasing the proximity of producers and users. Second, these options would enable compensation for TIH-related damage without bankrupting producers, transporters, or users. The third benefit is a transition plan that would balance equity and speed.

### *Improve Supply Chain Operations*

While internalizing the TIH externality will encourage product substitution and shorten transportation risk through production or usage relocation, TIH shipments will undoubtedly continue. Therefore efforts to improve the quality and reliability of the TIH supply chain must continue. This paper has described an array of industry initiatives aimed at improving safety and security of TIH shipments. Many of these efforts are already in the design or implementation stage, such as tank car redesign and improvements in rail employee hours-of-service rules and better chain-of-custody procedures. When positive train control is implemented, it should also enhance the safety and security of TIH shipments.

Routing TIH shipments to minimize risk is another operational action which is being undertaken. The supply chain participants consider routing in decisions on production, transportation, and sourcing. Recent rail regulations require railways to undertake more formal assessment of routing options but, while there are some opportunities to improve safety, the tradeoffs are complex and do not yield simple solutions.[192] As the rail industry learns to optimize the tradeoffs, the desirability of implementing event-related re-routing rules should also be explored. For example, federal regulations might be instituted to limit TIH shipments from passing within a certain number of miles of an outdoor event where the expected attendance is above a certain threshold number. Such rules might substantially reduce the availability of attractive targets for terrorists hoping to use TIH against crowds as a weapon of mass destruction, and also would limit the damage resulting from any accidental release, while keeping disruption of the TIH supply chain at more manageable levels. Any such limitations should be based on rigorous risk assessment that balances safety and security with the operational impact to the supply chain.

### *Enhance Emergency Response and Public Information*

The extent of human injury and property damage from a TIH release is directly related to the effectiveness of the emergency response. Several factors limit the ability of TIH emergency responders to mitigate losses. First, immediate and accurate information about the specific product that has been released and the conditions and circumstances of the release are essential, because TIH products with different characteristics require different actions to mitigate damage. Confusion about what product was released has, in past accidents, resulted in injury to first responders and the public. Second, a release could take place anywhere along 140,000 miles of freight rail infrastructure, and thus any and all of approximately one million first responders must have at least a rudimentary understanding in dealing with a TIH release. Third, better and more quickly available meteorological information is needed to improve public protection and mitigation measures.

The adoption of crisis management best practices into the emergency response process should provide first responders with better information for decision making, decreasing the risk of damage to themselves, the general populace, and property. Information is of limited value without local emergency response capabilities to take advantage of that information in order to contain released chemicals and protect residents. Therefore the challenge of TIH requires broad support for both the specific challenges and the more general emergency response infrastructure. Ongoing and increased support for a robust

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[192] Glickman, Erkut, and Zschocke, "The cost and risk impacts of rerouting railroad shipments of hazardous materials."

emergency response infrastructure capable of addressing diverse public health challenges is essential to minimizing the damages associated with the transportation of TIH.

In addition to better training for first responders, public education will be needed on how to interpret and follow warnings and instructions from emergency operation centers, such as the best direction to flee a release cloud, or when and how to seek shelter in place. Education will also need to be repeated from time to time as populations move and age.

### *Rationalize Regulatory Framework*

A broad range of federal, state, and local regulatory agencies are involved in rule making and oversight that applies to TIH. As part of the U.S. Department of Transportation, the Pipeline and Hazardous Materials Safety Administration (PHMSA) has broad responsibilities for hazardous materials regulation. The agency also provides grants to states to improve HAZMAT emergency response. Within PHMSA, the Office of HAZMAT Safety (OHM) oversees HAZMAT transportation, by issuing regulations and performing inspections of shipper and carrier facilities. Also part of the DOT, the Federal Railroad Administration (FRA) regulates rail operations and supports rail safety research.[193] The FRA has more rail inspectors in the field than any other agency. However, the Homeland Security Act of 2002 gave lead authority to the Department of Homeland Security (DHS) for "security activities in all modes of transportation"; within DHS, the Transportation Security Administration (TSA) is designated as the "lead federal entity" in transportation security matters.[194] Memoranda of Understanding between DHS and DOT are supposed to coordinate the roles of TSA, PHMSA, and FRA in transportation security, so that TSA has the lead in developing national strategy for transportation security, PHMSA has the lead on pipelines and the responsibility for "promulgating and enforcing regulations and administering a national program of safety, including security, in multimodal HAZMAT transportation," and FRA has the lead on rail safety. However, significant potential for confusion or conflicting priorities remains.

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[193] FRA, "Regulatory Overview: Safety Rulemaking, Reports, and Program Development," September 28, 2007, <www.fra.dot.gov/downloads/Safety/regulatory_overview.pdf>.

[194] "Annex to the Memorandum Of Understanding between the Department of Homeland Security and the Department of Transportation Concerning TSA and PHMSA Cooperation on Pipeline and Hazardous Materials Transportation Security," <www.phmsa.dot.gov/staticfiles/PHMSA/DownloadableFiles/Annex%20to%20MOU%20between%20TSA-PHMSA.PDF>.

A key lesson from the experiences with environmental externality was that concentrating responsibility at a single federal agency, the EPA, was critical for addressing these controversial issues successfully. In the case of TIH, multiple regulatory bodies provide unique and specialized capabilities, but whether it is desirable to concentrate more authority under one agency should be evaluated. It might well improve the focus on TIH priorities and make the regulatory process more efficient. PHMSA might be well-positioned to take on the lead regulatory role for TIH, because the organization has a deep technical foundation in TIH and other hazardous materials. It also has a view of the entire supply chain, unlike other agencies such as the FRA that are more centered on one aspect of the overall TIH safety and security issue. However, these advantages would have to be weighed against PHMSA's lesser knowledge of railroad operations.

Achieving consensus on regulatory rationalization is likely to be difficult, as each regulatory agency has its own constituents and may be reluctant to relinquish responsibilities and power. The recommended action in this area is, therefore, that the Secretary of Transportation, in consultation with the DHS and the EPA, should assess the specific regulatory items that should be centralized and analyze which organization would provide the best umbrella. An optimal outcome would be a TIH regulatory body with a critical mass of technical skill and political stature to convene interested parties, make difficult decisions, and create a unified course of action. Even before this happens, however, the other recommendations made in this paper can proceed.

### *Conclusions and next steps*

To achieve the goals outlined in these four broad areas for addressing the TIH rail transportation risk, four concrete next steps should be taken.

First, we recommend that the Secretary of Transportation, in collaboration with DHS and other relevant federal agencies, should convene a discussion among representatives of the affected parties to seek consensus on the principles to apply to policy development concerning safety and security of shipment of TIH chemicals. The most important issue is designing a claims fund, deciding how such a fund should be financed, and for what purposes its assets should be expended.

Second, this discussion should also seek a consensus on schedules and economic costs of initiatives ranging establishment of a liability or claims fund to encouragement of product substitution. The programs are proceeding and the technologies need to be encouraged. The more difficult issues involve timing for these efforts. What are realistic completion dates and priorities for deployment or adoption? How quickly should the old systems be phased out? These questions require the collaboration of the private sector with government, and involve difficult economic and risk tradeoffs.

Third, to address regulatory rationalization, the Secretary of Transportation should evaluate whether PHMSA, FRA, or another agency is best suited to take the lead in working with other agencies on redefining the roles of federal regulatory bodies to deal more effectively and efficiently with problems raised by TIH safety and security externalities.

Fourth, the Surface Transportation Board should examine how the common carriage obligations of the railroads and their rate regulation might be modified to include all the external risks as well as operating costs for incorporation in rate regulation for rail transport of TIH cargoes.

Finally, we recommend that the Department of Homeland Security, in collaboration with the Department of Transportation and other appropriate federal and state agencies initiate a focused study of specific security issues including: timing and routing of TIH shipments, preparedness of emergency management organizations and first responders, public education, and the role of intelligence and policy agencies and their sharing of information with private actors in the TIH supply chain.

There are many issues to address and challenges to overcome in addressing TIH transportation. A comprehensive supply-chain view of the safety and security externality of TIH rail transportation should make it possible to make significant progress in substantially reducing the risk of harmful TIH release.

| Glossary | |
|---|---|
| AAR | Association of American Railroads |
| ACC | American Chemistry Council |
| AFG | Assistance to Firefighters Grant |
| BNSF | Burlington Northern and Santa Fe Railway |
| BOE | Bureau of Explosives |
| CHEMTREC | Chemical Transportation Emergency Center |
| CP | Canadian Pacific Railway |
| CPR | Conditional Probability of Release |
| CSX | major east coast railroad [Not an acronym] |
| DHS | Department of Homeland Security |
| DOT | Department of Transportation |
| EAS | Emergency Alert System |
| EMS | Emergency Medical Services |
| EPA | Environmental Protection Agency |
| FAST3D-CT | Three-dimensional computational fluid dynamics model for contaminant transportation |
| FDIC | Federal Deposit Insurance Corporation |
| FRA | Federal Railroad Administration |
| GATX | Formerly General American Transportation Company (Note: No longer its name) |
| HAZMAT | Hazardous Materials |
| HEMP | Hazardous Materials Emergency Preparedness Grant |
| ICC | Interstate Commerce Commission |
| IST | Inherently Safer Technologies |
| LEPC | Local Emergency Planning Committee |
| NFPA | National Fire Protection Association |
| NGRTC | Next Generation Rail Tank Car Project |

| | |
|---|---|
| NOx | Nitrous Oxide |
| NRC | National Response Center or National Research Council |
| NS | Norfolk Southern Railway |
| NTSB | National Transportation Safety Board |
| O-D | Origin-Destination |
| OHM | Office of HAZMAT Safety |
| ONR | Office of Naval Research |
| OSLTF (or OSL-TF) | Oil Spill Liability Trust Fund |
| PHMSA | Pipeline and Hazardous Materials Safety Administration |
| PHMSA-RSPA | Pipeline and Hazardous Materials Safety Administration, Research and Special Programs Administration |
| PTC | Positive Train Control |
| R&D | Research and Development |
| R/VC | Revenue to Variable Cost |
| RAR | Railroad Accident Report [this acronym not used in the paper] |
| RFIT | Radio Frequency Identification Tag |
| SAC | Stand Alone Cost |
| SAFETEA-LU | Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users |
| SARA | Superfund Amendment and Reauthorization Act of 1986 |
| SEPC | State Emergency Planning Committee |
| SO2 | Sulfur Dioxide |
| STB | Surface Transportation Board |
| TCC | Tank Car Committee |
| THREAT | Tool for HAZMAT Rerouting Evaluation and Alternative Transportation |
| TIH | Toxic Inhalation Hazards |
| TRANSCAER | Transportation Community Awareness and Emergency Response |
| TRB | Transportation Research Board |

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|---|---|
| TRIA | Terrorism Risk Insurance Act of 2002 |
| TSA | Transportation Security Administration |
| TTC | Transportation Technology Center |
| UP | Union Pacific Railroad |
| URCS | Uniform Rail Costing System |